ENVIRONMENTAL FACTORS INFLUE[illegible]ING IDEA PRODUCTION IN A RESEARCH LABORATORY

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ENVIRONMENTAL FACTORS INFLUENCING IDEA PRODUCTION IN A RESEARCH LABORATORY

by

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B.S., Massachusetts Institute of Technology
(1949)

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(1951)

SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

at the

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1962

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School of Industrial Management

Certified by ..... Donald G. Marquis
Faculty Advisor of the Thesis

May 15, 1962

Professor Philip Franklin
Secretary of the Faculty
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Professor Franklin:

In accordance with the requirements for graduation, I herewith submit a thesis entitled " Environmental Factors Influencing Idea Production in a Research Laboratory".

I would like to express my sincere thanks to all of the one hundred and fifty seven respondents who gave so generously of their time and effort. And many thanks are due to Professors Donald G. Marquis and Tom Lodahl for without their encouragement and abilities, the crystallization of the author's vague feelings into a practical project would never have occurred.

Sincerely yours,

William E. Stoney, Jr.

WES/c

ENVIRONMENTAL FACTORS INFLUENCING IDEA PRODUCTION IN A RESEARCH LABORATORY

by

William E. Stoney, Jr.

Submitted to the School of Industrial Management on May 15, 1962, in partial fulfillment of the requirements for the degree of Master of Science.

ABSTRACT

The purpose of this investigation is the determination in quantitative form of those environmental factors in a research laboratory which have proved most effective in stimulating the production of ideas, and the analysis of the relative importance of those factors as it varies between sub-groups in the laboratory.

The data were obtained from a questionnaire given to 157 research professionals in two different divisions at the Langley Research Center of the NASA. The respondents were asked to choose up to six ideas or research contributions which they felt to be among the better made by them in the course of their career. These contributions were not identified in their replies except for a self-rating by the respondent on the general type of work, its originality and its final usefulness. Three questions were asked about each contribution. They were asked to choose from a list of forty one items (such as NASA reports, technical society journals, NASA sponsored graduate study, immediate supervisor, visits to industry or universities and work on or for a development project) those which had been most significant in

(a) The choice and definition of the problem
(b) The solution of the problem
(c) Motivating interest in the problem

The results are presented as ratios of the number of times an item was mentioned to the total number of choices. The individual items are grouped into seven classes; literature, education,

supervisors, co-workers, formal meetings, outside contacts and work experience. Comparisons of the response ratios among these classes are made for

(a) all non-supervisory replies
(b) between supervisory and non-supervisory replies
(c) between the two divisions
(d) between a high performance and a low performance group
(e) between a high performance group and a group which rated their contributions as highly original.

The most important single factor in the choice and definition of problems is the supervisor. Since the supervisors group was made up of principally the two lowest levels and since they themselves did not emphasize their own supervisors as strongly, the data indicate that problems are being chosen and defined at a low level in the laboratory hierarchy. Work experience and literature are second in importance for the total group but their influence is strongly different in each division. Formal meetings, outside contacts and education received very low responses, which is a surprising result since many of the individual items in these classes were designed by management specifically for greater internal and external communication of ideas and transmittal of professional skills.

The most important factor aiding the solution of problems is literature and this is true for all sub-groups except the supervisors who indicated their own work experience as being slightly more important. In contrast to the selection of problems the divisions exhibit little difference in their use of the environment to solve problems. Supervisors are a low fourth in importance in the solution of problems which compares with their dominating position in the choice of problems.

The responses to the motivational factor question reproduce the data of previous investigations in that professional motivations such as unusual fascination with the problem and desire for professional recognition are more important than organization motivations such as chance of promotion or pressure from supervisor.

The results of the present study indicate the possibility of developing quantitative indices of the differential use by researchers of environment sources of ideas. Such indices could be used to characterize different types of research work, or different laboratory groups, or different levels of research competence. Perhaps more importantly, the over-all findings provide a basis for designing changes in a laboratory environment to enhance the production of ideas in the identification and solution of research problems.

Thesis Supervisor: Donald G. Marquis

Title: Professor of Industrial Management

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STUDY OF THE ENVIRONMENTAL FACTORS AFFECTING RESEARCH WORKERS

Purpose

The attached questionnaire is an attempt to determine the relative value of the environmental factors which affect the research worker in the planning and performance of his work. The results may provide insight into the communications patterns within our Center which can be useful to those who have to provide support and organization for the workers. One part may also help (those who are attempting to) understand how ideas are generated in our field of Research and Development again in the hope that organizational factors can be found which would add to the individual's ability to contribute creatively.

Method

The questions we are attempting to study are difficult to objectify. Generalizations and anecdotal material come easily to mind but do not provide means of quantitative comparison. The method described below has been used with some success in previous studies and appears to be a useful way of attacking the problem at hand. However, it is experimental and a page has been provided at the end of the questionnaire on which you are invited to give your own evaluation of how satisfied you felt with the questions asked and with your own answers.

You are asked to focus your attention on six discrete ideas or contributions (or as many as you can up to that number) you have made in the course of your career at LRC. We wish you to consider as your idea or

your contribution anything you have done, said, or written which solved a problem on which you were working or which directed your own or others actions in a new direction. It is desired that you choose contributions which you feel to have been your best. Please do not take too exhalted a view of the magnitude of idea or contribution. The purpose of this questionnaire is to determine the effects of environment at all levels in the organization and thus in the sense required herein, all of you have contributed to the work you are doing.

While you are not asked to describe the contributions you have chosen, it will help you in giving objective answers if you will write your contributions on a piece of scrap paper before answering the questions. Number them from 1 to 6 and use these numbers to identify them in answering the questions. The first answer sheet (labeled Control Sheet) you are asked to fill out, requests particulars about yourself at the time each contribution was made. It also asks you to make some evaluations concerning your contribution - please, remember your answers will be anonymous and do not let modesty stand in the way of truth.

Please choose two contributions which were made after January 1, 1959, and four from any period before that time. Those with shorter work histories may not be able to do this of course and they are requested to simply choose as many discrete examples as they feel justified in separating for analysis. You may find that reports on which you were senior author provide the best focal point for consideration. They are especially helpful in fixing dates. It may be that you can focus on contributions which affected facility design or project progress but resulted in no written reports. Those of you in administrative positions may identify discrete ideas

that initiated new areas of research or changed the direction of or solved the problems of those working under you. In this connection your decision to foster or push certain lines of effort, though the content of the program may have been originated by others, can be considered your contribution.

Three Questions

Discussions with research people at LRC indicated that the laboratory environment could be thought of as affecting their work in three distinct ways.

(1) Choice and definition of problems on which to work
(2) Solution of problems of in-process work
(3) Motivation aids

Each of these headings make up a single questionnaire. These questionnaires ask you to select the most significant environmental factors directly aiding your ability to make each of the contributions you have chosen. Since the purpose of this study is a quantitative comparison of the various sources, aids and stimuli which surround the researches at LRC, a list of environmental factors has been developed which attempts to include all important types. However, as noted on the reply forms, you are invited to add your own if you feel that important items have been overlooked. The list is presented on separate sheets in two parts, the first part containing items which may be used for answering the first two questions, the second part for the third question. As an aid to answering the questions it is suggested the lists be kept at hand where they can be surveyed continuously while answering.

Anonymity and Procedures Used to Preserve It

The results of this survey will be presented only as environmental factors frequency distributions as functions of the various control factors. No names will be used, nor indeed will be known by the investigator. No one at LRC will see your completed forms except the investigator.

To accomplish this you have been given sheets with numbers on them (please make sure all your sheets have the same number) and an envelope with the same number. After completing the questions, place the five sheets (1 Control Sheet and the 4 Question Sheets) in the envelope - seal it and give it to your immediate supervisor.

It remains only to thank you for your efforts. The only tangible reward that can be offered is the assurance that the results of this survey will be available to all who contributed to it.

ENVIRONMENTAL FACTORS - QUESTIONS 1 & 2 - LIST I
(Separate these sheets for use during answering)

Literature

(1) NASA Reports (all types) written at LRC
(2) NASA Reports (all types) written at other Centers
(3) LRC internal memorandums
(4) NASA Subcommittee reports
(5) Technical reports - Non-NASA laboratories
(6) Technical society journals - periodicals
(7) Semitechnical or popular science periodicals or trade journals
(8) Text books
(9) General literature

Note: If the LRC Library was the source of the literature place an L after the number chosen.
If privately owned place a P.
If you feel that your reading at home was an important factor place an H after the number.

Education

(Only to be noted if the education factor directly influenced the idea focused on)

(10) Preemployment schooling
(11) Post-employment schooling - that is, NASA-sponsored graduate studies
(12) Knowledge of more than one field - that is, stability control and electronics or physics and aerodynamics

Personal Communication

(13) Immediate supervisor
(14) Higher than immediate supervisor

Note: If you feel you can differentiate, place A after number for assigned tasks and S for suggested. Use number alone if supervisor was source of help or advice - or if you cannot differentiate his influence.

(15) Coworkers actively engaged with you in work under consideration - work setting
(16) Others in your functional organization - work setting
(17) LRC friends - social setting
(18) Formal conferences or meetings inside division
(19) Formal conference or meetings with other divisions
(20) Monday night research meetings
(21) Editorial committees
(22) NASA conferences -that is, High-Speed Aero. Conference- X-5 Conference
(23) Technical society conferences - that is, IAS, ARS, etc.
(24) NASA Subcommittee meetings
(25) LRC Subcommittee meetings
(26) Industry or university visitors to LRC
(27) Your visits to industry or universities
(28) Your personal acquaintance and communication with outside experts in your field
(29) Supervision or aiding of subordinates

Personal Work Experience

(30) Similar research work
(31) Work on facility design
(32) Work on or for a development project
(33) Free time (that is, normal workload allowed time for individual exploration, thinking, and reading)
(34) Work at home or at the laboratory outside usual working hours

ENVIRONMENTAL FACTORS - QUESTION 3 - LIST II

Motivations

(Only as you can relate it directly to extra effort on idea under consideration)

(35) It was your "baby" - You originated job
(36) Working for Conference Report
(37) Competition with other divisions, people, techniques - laboratories
(38) Unusual fascination with problem
(39) Chance of promotion
(40) Pressure from superior - that is, setting of deadlines, constant inquires, etc.
(41) Desire for professional standing - prestige - publication

CONTROL SHEET

(This sheet to be turned in)

Completed by No. ___

The data on this sheet will be used as control variables - that is as basis for comparison of the answers given to the three questions. Please quote your age, administrative position, (division, branch or section head or assistant) and division at the time you made the contribution under consideration.

The remaining columns are labeled for your answers to the questions noted below. Simply place the number of the phrase you feel most applicable in the correct column and do this for each contribution. Remember these answers will be anonymous and do not let modesty distort your true opinion.

A. This contribution was part of work on, or culminated in
   1. A research report
   2. New facility, test technique
   3. Project or development work

B. Considering the originality of this contribution, its uniqueness, freshness, creativeness and imagination, it can be considered
   1. Very similar to work done elsewhere-or fairly obvious extension of previous work
   2. Derived from other work but requiring some clever new applications or methods
   3. Fairly original - used old techniques in new ways
   4. Highly original - new techniques used in novel ways

C. Considering the final use of this contribution - its importance; breadth of application, the degree to which it enlarged insights and understanding in its field it can be considered
   1. A small step forward - filled in a few minor areas
   2. Was fairly useful - stimulated some follow on work
   3. Was very useful - stimulated considerable follow on work
   4. Made very important contribution - changed basic direction of work in area - opened up large new areas

D. Considering that time plays an important part in the usefulness of much of the work at LRC do you feel that your contribution was made less valuable because of delays caused by
   1. Getting authorization to work on it in the first instance
   2. Contracting red tape
   3. Lack of administrative support - priority problems
   4. Publication procedures

Contribution #	At the time you made each contribution						
	Age	Admin. Position	Division	A	B	C	D
1							
2							
3							
4							
* 5							
* 6							

* Place two contributions made since Jan. 1, 1959 opposite these numbers throughout quiz

NASA - Langley

QUESTION 1

(This sheet to be turned in)

Completed by No. ___

Choice and Definition of Problems

By this is meant all matters which bear on the fact that you started to work on each of the problem areas you chose on sheet 1. For a great many, one of the most important influences will simply be No. (13) or No. (14), that is, either assignment or suggestion by an immediate or a higher supervisor. Caution - we are interested only in the direct influences on you - not on where the idea or problem may have originated. Even though you may know of its source indicate only how it got to you.

For each contribution you have identified please list in order of importance the environmental factors you think were of most significance in the choice and definition of that contribution. It is requested that you try to use the items on the list (using the numbers provided) but you may and it would be very helpful if you would, write in different ones of your own choosing. Please keep Environmental Factor List I and your own list of contributions at hand while answering.

No. 1

No. 2

No. 3

No. 4

No. 5

Since Jan. 1 1959

No. 6

NASA - Langley

QUESTION 2

(This sheet to be turned in)

Completed by No. ___

Solution to Problems of "In-Progress" Work

By this is meant all matters which aided you in some significant manner in making contribution chosen.

For each of the contributions you have identified, please list in order of importance the environmental factors you think were most significant as sources of aid to you in working on and solving the problem to which you made your contribution. Again try and use the items on the list (by noting their number) but feel obligated to write in different items if you think they were significant. Please keep Environmental Factor List I and your own list of contributions at hand while answering.

No. 1

No. 2

No. 3

No. 4

No. 5

Since Jan. 1 1959

No. 6

NASA - Langley

QUESTION 3
(This sheet to be turned in)

Completed by No. ___

Motivational Factors

By this is meant those environmental factors which you think inspired you to greater than average effort on the problems under consideration. You may well feel that your effort was not greater than usual and therefore check nothing. This is not an attempt to determine your basic psychological motivations but rather to evaluate the effect of various outside pressures or stimulations together with some of the more obvious internal motivations.

For each of the contributions you have identified please list in order of importance any motivational factors you feel made a significant difference in your effort level. Again try and use the items on the list (by noting their number) but feel obligated to write in different items if you think they were significant. Please keep Environmental Factor List II and your own list of contributions at hand while answering.

No. 1

No. 2

No. 3

No. 4

No. 5

Since Jan. 1 1959

No. 6

NASA - Langley

QUESTION 4

(This sheet to be turned in)

Completed by No. ___

Personal Reactions to Questionnaire

Since the problem for which you are filling out this questionnaire is complex and since the questionnaire method is itself quite experimental, your reactions to the purpose of the study, the filling out of the questionnaire, and the meaningfulness of the answers you gave are most important. Your comments and feeling on any and all phases are much needed and desired. Though in no way intended to restrict you, a few specific questions are noted below:

(1) Do you feel you understand the purpose of the questionnaire?

(2) Do you feel the method used can give significant results?

(3) Did you have a difficult time choosing "contributions"?

(4) Did you find it difficult to identify "environmental factors"?

(5) About how much time did you spend on the questionnaire?

NASA - Langley

ORIGINALITY AND PRODUCTIVITY RATING SCALE

As supervisors you are being asked to rate each of those who work for you on the attached scale. You will note on each rating only the number of the questionnaire which you gave to each subordinate. The scale was developed by a research psychologist and has been used in quite a few investigations at Research and Development laboratories. Its purpose is to allow a rating of an individual on scales for originality and productivity. Its use in this particular investigation will be for comparison of the environmental factors used by those rated high on each of the scales and those rated low. Since the names of the persons rated will not be known to the investigator nor to anyone else but you, and since you will not be able to score the ratings yourself, there is no danger of this information being used indiscreetly. Note - With ratings like these it is best not to spend too much time pondering each phrase - your first reaction is likely to be the most accurate.

CRITERION CHECK LIST FOR SCIENTISTS
(With permission from D. W. Taylor, Yale University)

Person rated is No._____

Place a check mark in the space to the left of each statement which applies to or describes the man being rated. Statements that do not apply should be left blank.

( ) He often introduces minor innovations in his work but rarely, if ever, makes a markedly original contribution.
( ) He contributes more of his own ideas to the problems he works on than does the ordinary worker.
( ) Given an unfamiliar problem, his first impulse is to consult a book or another person.
( ) By comparison with other people in such a job, he is outstandingly creative.
( ) Like most of us, he has occasionally devised an improved method or piece of equipment.
( ) He never has an idea of his own to suggest.
( ) Some of his ideas, while original enough, are also silly or bizarre.
( ) He shows signs of being one of the most creative men in this work that I have ever known.
( ) He does not have a great number of new ideas.
( ) He frequently has ideas.
( ) He has suggested many entirely new problems.
( ) He is somewhat hesitant about trying to work through a new problem entirely on his own.
( ) Now and then, he works out a somewhat ingenious hypothesis.
( ) Characteristically, even when faced with new problems of some complexity, he tries to think things through in his own terms.
( ) He seldom contributes new ideas.
( ) Once in a while he has an original idea.
( ) More than once he has shown us new ways of looking at results.
( ) Left to himself, he might have difficulty thinking up problems to investigate.
( ) Invariably his approach to anything is original and fresh.
( ) He does an adequate, but not an outstanding job of outlining new research proposals.
( ) His ideas are more likely to be conservative, rather than revolutionary.
( ) He worked out on his own, applications of his results to other problems or fields.
( ) He requires detailed instructions before he sets about a new job.
( ) He is something of an independent thinker.
( ) His output is somewhat below what one expects from the average worker.
( ) He does satisfactory work on assigned problems.
( ) He is one of our best men.
( ) He never seems to accomplish anything.
( ) He is on the borderline; capable of fairly good or average work, but inclined to fall below that level.
( ) He often does an outstanding job, even under adverse conditions
( ) The work he hands in is careless and superficial.
( ) His work is always done on time.
( ) He gets right down to work and doesn't waste time.
( ) In terms of quality, his work is about average.
( ) He has to be prodded continuously to keep him going.
( ) Both in terms of quantity and quality, his work leaves nothing to be desired.
( ) His work has to be checked for errors.
( ) He works steadily and tries to be thorough.
( ) He has an exceedingly large output.

( ) He tends to get off on to side issues and to wander from the point of a project.
( ) He struggles along, is fairly productive, and, under the best conditions, does a tolerable job.
( ) He never gives up on a problem until reasonable success has been attained.
( ) He seldom gets his projects done on time.
( ) He turns out a great quantity of work.
( ) Like most of us, he is inclined to make a few mistakes in his work.
( ) He can solve satisfactorily most of the problems that arise in connection with his work.
( ) His hard work has earned him the respect of his associates.
( ) He takes so long to do his work that sometimes the need for an answer to a problem passes before he is finished working on it.
( ) The ideas he proposes are nearly always productive.
( ) Stimulates others into generating ideas.
( ) Uses others effectively to stimulate his own thinking.
( ) Objectively critical.
( ) Quick to grasp and use ideas.
( ) Rapid flow of ideas.
( ) Original in research methods.
( ) Ingenious in constructing laboratory equipment.
( ) If one solution to a problem proves faulty, he already has another to replace it.
( ) Discovers many new problems as he proceeds in a research study.
( ) Not bound by his own field when following research leads.
( ) A real pioneer, not simply a compiler.
( ) Analyzes everything he encounters.
( ) Readily grasps relationships between seemingly unrelated things.
( ) Assembles sufficient data for valid conclusions.
( ) Unceasingly digs to the bottom of a problem.
( ) Self-reliant, but not overbearing.
( ) Always prepared for the next step.
( ) Initial reactions are negative.
( ) Sound judgment.
( ) Well-integrated personality.
( ) Fuzzy thinker.
( ) Absorbed in research.
( ) Stores information rather than understands it.
( ) Will do original work when on his own.
( ) Has the courage of his convictions in the face of adverse criticism.
( ) Wins the confidence of others.
( ) Provides leadership in science.
( ) Knows when and from whom to seek help.
( ) Probably in the wrong field.

CHAPTER I

BACKGROUND AND INTRODUCTION

Ideas are produced by people, but people do not exist or produce ideas in a vacuum. It seems reasonable that the quantity, quality and substance of the ideas produced by a researcher depend in some degree on the environment in which he works. This study undertakes to determine the types and relative importance of environmental factors significant in idea production at one research center. In addition the data are analyzed to bring to light any differences due to separate organizations within the laboratory or to the degree of creativeness of the individual researchers.

The concept for this study arose from the writer's interest in the creative act. A great deal has been written on this subject and there has been much effort in the past few years to make use of the techniques of modern psychology, sociology, and psychiatry in the investigation of the phenomena of creativity. (Ref. 1, 2) Most of this work has focused on the creator; how to identify him, how to predict his future performance, how did he get that way, how is he different from others, etc. There is relatively little work on the environmental sources of ideas.

The work that has been done in this area (ref. 3, 4, 5) is usually the result of the author's personal experience or of interviews with a relatively small number of research administrators or workers. The results are general, speculative and very often

contradictory. They do not resolve the problem of just what kind of environment is good for research, nor do they provide more than intuitive hints for the design of an environment capable of bringing out the best in the research personnel available.

The present work is directed to providing data which might help in environmental design or at least will provide quantitative data for comparison with the qualitative results noted above. Because of this it was necessary to choose methods and techniques different from most previous work. To provide sufficient material to make quantification meaningful, a questionnaire was given to one hundred and fifty seven research workers at a government research center. The questions asked were directed toward the external forces acting on the researcher in his creative moments rather than internal or psychological forces. *

In a few words, the purpose of this investigation is the determination of those environmental factors in a research laboratory which have proved most effective in stimulating the production of ideas, and the analysis of the relative importance of those factors as it varies between sub-groups in the laboratory.

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* One question did involve motivation, but the examples given were chosen to direct the respondents' thoughts to those kinds of motivation which were in some way capable of being affected by management and in that sense were external.

CHAPTER II

METHODS: QUESTIONNAIRE ON ENVIRONMENTAL FACTORS

Use

A questionnaire dealing with environmental factors affecting the production of ideas was given to all the professional personnel of two research divisions at the Langley Research Center of the NASA. These were the Aerophysics Division and the Advanced Materials and Physics Division.* Of the 119 professional people in the Aerophysics Division, 66 returned questionnaires and of the 135 professionals in AMPD, 91 returned them. The people involved are all engineers (predominantly aeronautical), mathematicians or physicists (possibly a few chemists) and their Civil Service grades run from GS-7 to GS-16. No person of under one year service is included. Twenty six of the 66 Aerophysics respondents had five years or less experience and 43 of the 91 replies from AMPD were from people of five or less years experience.

The use of the questionnaire technique for a very similar purpose was tested on a small scale (15 people) by Beach (ref. 6). The general form and content of his questionnaire were used in the present design. Beach noted the importance of prequestionnaire preparation of the respondents if satisfactory answers were to be obtained. Because of the size of the sample in the present study (157),

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* For ease of notation, Langley Research Center will be referred to as LRC and the Advanced Materials and Physics Division as AMPD.

it was impossible to devote personal attention to each. The general plan of the study was discussed in individual interviews with the division chiefs, their assistants, and several of the next line of supervisors, the branch heads. These interviews attempted to accomplish two objectives; first establish centers of understanding as to the purpose and content of the questionnaire in each of the divisions in positions from which its propagation would be natural and easy; and second, to use the experience of these people in designing the detailed items of the questionnaire. Interviews with several non-supervisory personnel also aided in this second objective. In addition, the questionnaire was designed to be self administering, that is, the sections on purpose and method were written so that the respondent would understand the purpose and the language of the questions without any other source of explanation.

The Questionnaire Itself

The following pages contain an exact duplication of the questionnaire as it was given to the research workers. The discussion following will assume that the questionnaire has been read. While reading the questionnaire, note carefully the definitions of the terms "idea", "contribution", and "environmental factors". Extreme care was taken to give these words precise meaning and examples were given which referred to the specific environment of the people involved. * "Idea" and "contribution" are used as

* The author's opinion was the criterion used since he worked at this laboratory for 12 years. The particular items on the list of environmental factors were compiled from the author's own experience and from suggestions made during the interviews. The list is long and very detailed but as many items were included as came to mind since aggregations of general catagories could be made from the specific items. Also it was felt that the inclusion of many items specific to the particular environment would stimulate the memories of the respondents.

synonyms, and some of the problems of their definitions are discussed in the following section. The meaning of environmental factors is best understood by reading the list of examples.

Rationale

The questionnaire is no "Topsy" nor is it completely derivative from Mr. Beach (ref. 6). This section presents many of the features of the questionnaire and discusses the rationale behind their design.

The questionnaire technique was chosen because an analysis in breadth rather than in depth was desired. By getting responses from 157 personnel working at all supervisory levels and in two quite different divisions, the answers could be expected to have some significance in the statistical sense. And the statistical situation is even better than the number of respondents implies since it is the individual contributions which are the significant items under investigation and each person was asked to answer each question for up to six contributions or ideas. For the most numerous breakdown in the analysis that follows - that is, all contributions made by people in a non-supervisory position, the total number of examples is (713).

Perhaps one of the most important features of the method used in this study is that the respondent is directed to choose specific contributions, to actually write them down and think about each as an individual event. Hopefully this avoids getting hazy, generalized feelings which may be conscious, but are more probably unconscious, integrations of both personal and observed experience. Data obtained by concentration on specific personal events should be more precise than general impressions. In other words, one filter has been partially removed from in front of the data and the integration process

put into the hands of the investigator who has the means for handling it in an objective and statistical manner.

Three questions are asked about each contribution: one on the choice and definition of the problem, the second on the solution of the problem and the third on the motivational factors affecting work on the problem. Originally (and this was the method used by Beach) it was thought that a single, free answer question such as, "Identify the environmental factors most helpful to you in producing your best ideas", would be sufficient. During the interviews, however, it became apparent that many people were inclined to say they never had had an idea in their life, they just worked on problems given them - or suggested to them by their boss. This type of answer probably means that they were using the word "idea" on too grand a level. The division of the question into three parts, origin, solution, and motivation, was to force their attention to the fact that they actually did contribute ideas, that they actually made use of the environment around them in many different ways in their personal solution to their problems and that they did not depend entirely on the ideas of their supervisor.

The division between origin and solution can be defended on rational grounds also. It seems reasonable to think that the mental attributes (or the psychology or the ability) of a self-starter (or a problem identifier or a problem definer) would differ in many ways from the problem-solver. One deals in an open-ended, the other in a closed-ended environment. In fact the difference is noted in our language as the difference between creative and ingenious or resourceful. This is what those who said they had never had an idea in their life were attempting to say. It is often said that creation is 90% completed once the problem is defined. In any case, there seems

to be a feeling that such a separation is one of kind and not just degree. However, if we accept this distinction as really true in our case, we must ask how can the use of the same factor list for both questions be explained?

Fortunately, for our purpose it is not necessary that we attend too strictly to these speculations or attempt to decide whether we are dealing with differences in kind or degree. It is sufficient to note that it is interesting to identify what portion of people are "self starters" by their answer to the first question, and that the verbal problem of the "I never had an idea" man is a real one.

The use of a separate question on motivation aids grew out of the interviews also. There seems to be a real difference of kind between the examples noted on List II and those on List I.

Once the decision to use three questions about each contribution had been made it seemed advisable to try and find out something about the contributions themselves and about the person who made them at the time he made them. The interviews turned up another interesting fact. Although all the people interviewed were at the second, third, or fourth level of supervision (from the bottom), none picked contributions from their supervisory experience when asked to choose an example to think about while identifying environmental factors. This was one of the reasons all respondents were asked to choose at least two items which occurred later than January 1, 1959, since this would force the present supervisors to choose contributions made while in their present grade - or perhaps their previous one.

The other reason for the time division is that the creation of NASA in October of 1958, marks a rather dramatic change in the

aims of the total organization and it is of interest to find if this change would affect such basic matters as those investigated by the questionnaire.

Four questions were asked about each contribution. They attempt to characterize the contributions in fairly broad and obvious ways which might be expected to relate to environmental factors.

Technique Evaluation

The final question was designed to determine the respondents' reactions to and difficulties with the questions. Since there was no chance to interview even a portion of the people questioned, the answers to this question are the only means available to determine the degree to which the instructions and purpose of questionnaire were understood.

Perhaps the best that an interviewer could require of his subject would be that the subject understood the purpose of the questions, that he was sympathetic towards their purpose in the sense that he felt it could be accomplished by the means being used, that he felt completely at ease with the terms and forms of the questions and that he felt it unnecessary, though repeatedly entreated, to add any factors of his own or make any comments on the form or content of the questions. It would also add to the interviewer's confidence if it was found that the respondent was willing to devote a considerable amount of time to the task assigned.

The five questions asked in Question 4 were designed to provide the researcher with just such data. The results show that there are only 31 respondents (out of 157) who classify as perfect subjects, and even this number should be reduced since 10 of these added comments of one kind or another. The following paragraphs will summarize the faults of the "imperfect" subjects.

The first question "Do you feel you understand the purpose of the questionnaire?", was answered negatively by only 14 out of the 157 respondents, and indicates that the questionnaire was understood as a whole.

Perhaps a more important part of understanding involves the subjects' comfort with and ability to use the word definitions and idea forms imposed by the questionnaire. Two questions (the 3rd and 4th of Question 4) provide data on the reaction to the most significant and also most difficult concepts used in the questionnaire. The fact that 52 out of 157 respondents were able to answer "no trouble" to both of these questions and that only 27 answered that they had trouble with both (leaving 68 who reported trouble with only one or the other, since 10 abstained from answering the question) leaves the question of understanding somewhat up in the air. It does point up the fact that the concepts involved are not dictionary simple. Also the fact that slightly more trouble was experienced with identifying the "environmental factors" (69) than with choosing the "contributions" (53) is not easy to interpret, since there was usually no comment on the degree of difficulty encountered in the task.

The co-operation of the respondents was excellant. In spite of the fact that a fair number (45) answered the second question ("Do you feel the method used can give significant results?"), with a no, from which it might be inferred that they would not feel it worth while to co-operate, the high average time spent in filling out the questionnaire (1 1/2 hours) contradicts that inference, as well as the fact that the times for the 45 no's were not markedly different from their yea-saying brothers.

CHAPTER III

METHODS: THE CRITERION CHECK LIST

Description and Background

Each supervisor in the two divisions of the Center was asked to rate each of his immediate subordinates using the check list presented on the next two pages. The only information provided the supervisor about the list was that contained in the instruction sheet attached to it. No mention was made of the fact that three different scores were to be obtained from the list (nor were the scales of each indicated as they are on the sample copy) - nor was the manner of scoring indicated.

The check list is identical to that used by Dr. Calvin W. Taylor of the University of Utah in a project for the Air Force (ref. 7). It contains Dr. Donald W. Taylor's check lists for creativity (C_1) and productivity (P_1) (ref. 2-1957) and a supplementary list developed by Dr. Calvin Taylor.

The C and P scores are derived by weighting the individual items checked and recording the median values. The U score is simply the total number of items checked less certain items which are weighted negatively. The C scale was developed to measure creativity and the P scale productivity. Reference 7 does not mention what factors were considered in the design of the U scale but from inspection it seems to consider the general characteristics required of a good research worker. This problem of criterion for "the good guys" and "the bad guys" in research is a complex

and still unsolved problem and has received considerable attention in recent years. (Ref. 2, 7)

The use of some measure of individual performance was desired because it was felt that the environment might be used in quite different ways by people of high and low performance. The check list used was chosen because it was simple and easy to administer and because it had been already used in several government research laboratories including one other NASA laboratory (Lewis). It uses terms that would be readily understood by anyone in the LRC research environment and its form (the checking of a number of phrases - none of which in themselves have high emotional loadings of good or bad) would be more acceptable to those doing the ratings than other rating methods. *

Check List Results

Table I summarizes the results of the ratings and the correlations between them. **

---

* One higher supervisor took the trouble to go over his supervisor's ratings and reported that he found himself in quite general agreement with their checks. He said in fact that the criterion check list was an excellent tool in his eyes but he was sorry he couldn't say the same for the rest of the questionnaire.

** Correlation factor $$R = \frac{\frac{1}{N}\sum (X - \overline{X})(Y - \overline{Y})}{\sigma_X \quad \sigma_Y}$$

where N = Total number of items = 157

X, Y = scores of two classes being compared

$\overline{X}$, $\overline{Y}$ = mean scores of two classes

σ_X, σ_Y = sigmas of two classes

	C	σ_C	P	σ_P	U	σ_U	Correlation R C P	C U	P U
Aerophysics	35.4	9.75	42.8	10.5	4.94	4.36	.72	.73	.80
AMPD	40.4	11.3	44.8	8.82	8.88	7.39	.63	.84	.65
Total	38.3	11.0	44.0	9.61	7.21	6.58	.66	.81	.66
Taylor (ref. 2, 1957)	42.6	10.4	46.4	8.4			.67		

Table I: Check List Results

This table reveals the difference between the two divisions in C but not in P (the difference in C is statistically significant at better than the .01 level - the P difference is not significant statistically). The difference in the U scores is even wider than the C difference and is in the same direction.

The correlations bring up the question of just what characteristics the lists are measuring. In particular all the correlations are high enough to allow the assumption that the different tests are measuring the same factor to a considerable extent. A practical example of what the correlation numbers represent can be seen in Table II where the number of people in each quartile who were in both the C and P quartile noted is presented as a ratio to the total number of people in the quartile.

	Ratio of people common to both C and P quartiles to total in quartile	
	Upper quartile	Lower quartile
Aerophysics	11 : 16	7 : 16 *
AMPD	11 : 21	13 : 21

Table II: Number of People Common to Both P and C Quartile Groups

* See pg. 13

Because of these high ratios of a common population only one group (C) was chosen for analysis of the environmental factor variation.

Figure 1 presents the frequency profiles of the three ratings for each of the two divisions. Again the difference between the two divisions in C and U is obvious. Taken at face value, the results indicate a greater number of creative researchers in AMPD than in Aerophysics but about the same number of productive workers. However, it is much more likely that, since these ratings are in the organizational sense, self ratings, the real difference being expressed by the creativity scores is probably the difference in value climate used by the supervisors as they rated their subordinates. The direction of the difference is such that the characterization of Aerophysics as being the most scientifically oriented of the two divisions (see discussion, Chapter VII), is born out by the scoring, since such a group might be expected to have higher standards (especially for such a value-loaded word as creativity) which would be expressed by finding fewer people who deserved really high scores.

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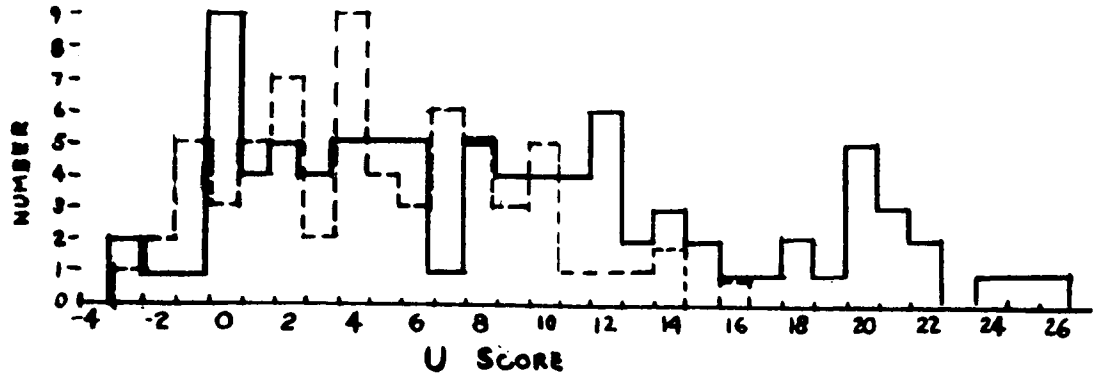
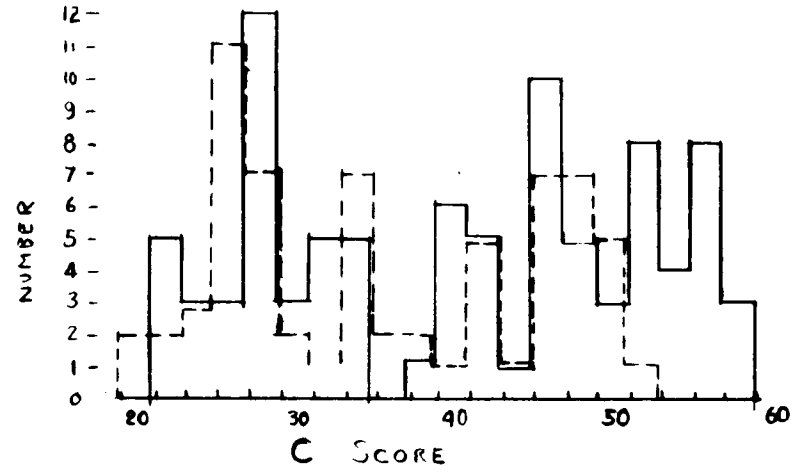
* All boxes except the lower quartile Aerophysics exceed chance on at least the .05 level for the hypothesis that the criteria C and P are independent.





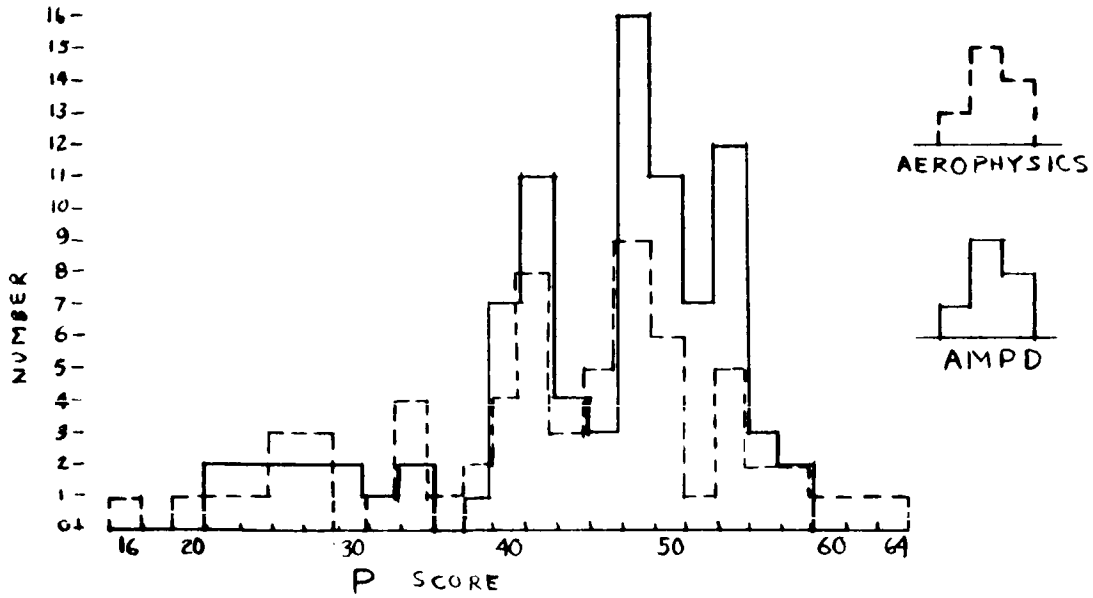


FIG. 1 DISTRIBUTION OF U, C AND P CHECK TEST SCORES

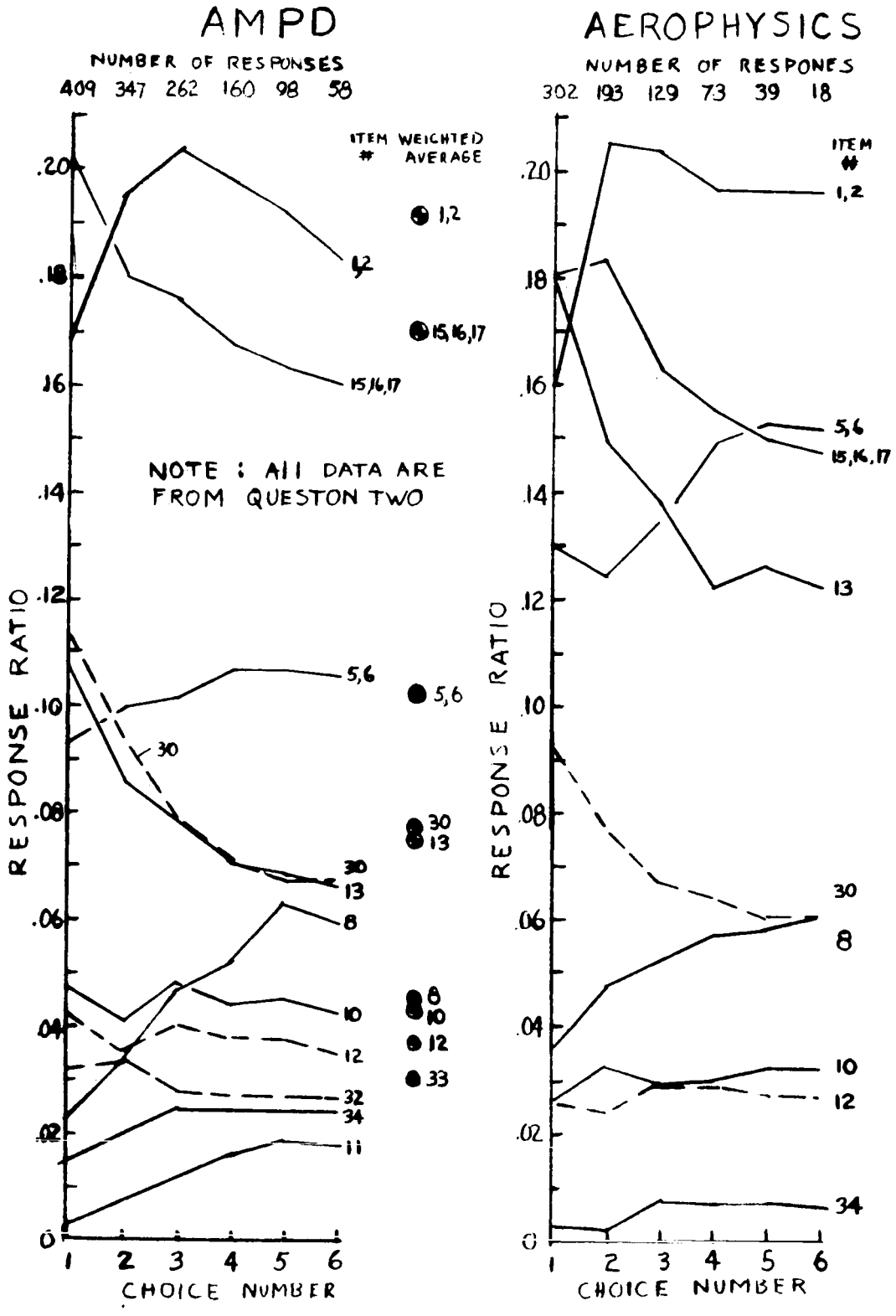


FIG 2 COMPARISON OF DATA REDUCTION METHODS

CHAPTER IV

METHODS: DATA REDUCTION

The Reply Ratio

The major results of the survey are presented in the form of bar graphs representing the total number of times the factor was indicated as being among the first four most important factors chosen by the respondents. The data have been made comparable by dividing such totals by the total number of factors chosen in the first four places.

There are other ways to present data such as obtained by this questionnaire. The principal reason for the method used is that it makes data reduction reasonably simple and that no other more complex scheme seems justified. The results of experimenting with other schemes are shown in Fig. 2. The data are for Question 2 (factors in solving problem) for all contributions except those made by supervisors and are presented for AMPD and Aerophysics separately. The data are presented as response ratios. The column indicated by 1 for each group is the sum of the first choices for each factor divided by the total number of first choices. The second column is the sum of the first and second choices for each factor divided by the total number of first and second choices; and so on, for the columns marked 3, 4, 5, and 6*. Symbolically

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* See pg. 15

$$\text{(reply ratio)}\quad (R) = \frac{\sum \text{Choice 1 + Choice 2} \cdots \text{Choice N}}{\sum \text{Total 1 + Total 2} \cdots \text{Total N}} \qquad \text{where N = 1, 2, 3, 4, 5, and 6 in turn}$$

To make the plot readable not all the data have been presented (some data in the R < 04 range have been omitted) and several factors have been grouped into single categories. The factors are noted on each line by the numbers used for them in the questionnaire environmental factor lists.

For our present purpose, the interesting feature of Fig. 1 is the shape of the individual curves. Note that as more choices are included, many of the reply ratios change in value sharply, principally the more important ones. In fact the change in values causes a change in the relative importance of several items as we move from the first choice to the sum of the first and second. As choices are added into the total above the second there is a definite tendency for the values to stabilize. Note that only one pair of factors changes order after the 4th choice is included and that one by only a small amount. Note also that the number of choices thrown away when the fifth and sixth choices are eliminated is small (only 12%).

Another method used often in rating ranked replies involves to use of weights of various amounts - usually with the purpose of emphasizing the first or earlier choices. As an experiment the AMPD data were weighted by multiplying the first choice by 6, the

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* Six was chosen as a cut-off point for card indexing the data of questions 1 and 2 since very few people presented more than 6 choices as can be seen from the numbers on Fig. 2. Only four choices were card-punched for the 3rd question for the same reason.

second by 5, the third by 4, etc. Summing up the resulting values the R numbers shown by the symbols were obtained. It is interesting - but undoubtedly accidental, that the values obtained in this way compare fairly closely with the sum of the first 4 choices. Since it was more difficult to reduce data in this fashion and since neither logic or any real difference in results recommend it, the weighting method was rejected.

Thus, the sum of the first four was chosen as the method of presentation since it seemed to represent the sense of all the data and since it seemed desirable to avoid excessive influence by the first choice items.

One very interesting and important feature of the results in Fig. 2 is the strong similarity of the shapes of the curves for each item between each division, even when they show large differences in value; for example factor 5, 6 or factor 13. This indicates a certain consistency in the order in which the factors are chosen and adds another reason for trusting the sum of four choices as representative of the whole.

Environmental Classes

The number of individual items involved (34) would make the analysis extremely complex if all items were compared individually and the small number chosen of many of them would probably make most sub-group variation in them statistically insignificant. Also, the individual items do fit into logical classes and these classes have the advantage of not being applicable to LRC only. These general classes are indicated by the outer boxes on Figures 3 and 4 and are as follows:

	Individual Item Numbers Included
Literature	1, 2, 3, 4, 5, 6, 7, 8, 9
Education	10, 11
Supervisors	13, 14
Co-workers	15, 16, 17
Formal Meetings Inside Laboratory	18, 19, 20, 21, 22, 24, 25
Outside Contacts	23, 26, 27, 28
Personal Work Experience	12, 29, 30, 31, 32, 33, 34

Note that this breakdown follows the original factor list except that items 12 and 29 have been placed in the category of Personal Work Experience, and that Personal Communication has been divided into four classes; Supervisors, Co-workers, Formal Meetings, and Outside Contacts.

Although the motivational factors of question three were not grouped into classes at all in the questionnaire, they too fall into two classes quite naturally. These are as follows:

	Individual Item Numbers Included
Professional Motivations	35, 38, 41
Organizational Motivations	36, 37, 39, 40

All the items classed as organizational motivations are more or less under the direct influence of the research management. This separates them significantly from the remaining three items classed as professional motivations since these depend primarily upon individual attitudes which are controllable by management - if at all -

only in a very loose way.

Statistical Significance

In the analysis which follows, all comparisons have been examined for statistical significance by use of the Chi - square test. The significant differences are noted on each figure by presenting the level of significance as a ratio. For example, if the difference exhibited by the data is sufficiently large that it could be expected to occur by chance only once in one hundred cases, this is indicated by the notation $P < .01$. The differences are considered significant if $P < .05$. The absence of a number after the bars being compared signifies that the difference between the items is not significant at the .05 level.

CHAPTER V

ENVIRONMENTAL FACTORS AFFECTING CONTRIBUTIONS OF NON-SUPERVISORY INDIVIDUALS

In this chapter the data are treated as coming from a homogeneous group. In later chapters the responses are analyzed to discover differences caused by sub-group characteristics. All responses are included except those made about contributions made by supervisors. Omitting supervisory contributions eliminated 67 out of 777 total contributions and 205 out of 1,482 responses for question one and similarly small portions for the other questions. The supervisor's responses are separately analyzed in the next chapter and compared with the presently considered non-supervisory results.

The response ratios are presented as bar graphs in Figures 3, 4, 5, and 6. Each individual factor is listed and numbered exactly as given in the questionnaire environmental factor list. The filled in bars represent the response ratios of these individual factors. In addition, the factors are grouped in classes as described in Chapter IV and the response ratios of these classes are noted by the solid lined boxes enclosing the grouped individual items. Eight of the literature items are grouped in pairs and their paired response ratios shown by the dotted boxes.

Question One: Choice and Definition of Problem

The first question asked the respondent to identify the environmental factors thought to have had the most significance in the choice and definition of each of the contributions listed by the respondent as among his better efforts. Figure 3 shows that among all factors the immediate supervisor was chosen in nearly one third of all the cases. This, however, is one situation in which the use of the first four factors chosen by each respondent masks the importance of a factor. If we examine the first choice alone, we find that 53.5% of the respondents chose the immediate supervisor while another 12.5% noted a higher supervisor. Thus 66% of all respondents find on looking back into their past work history that the most important factor in their choice of an idea on which to work was a supervisor. The supervisor tended to be chosen first or not at all - for both immediate and higher supervisor. The total number of choices of the supervisor are, in order, first, 380; second 39; third 10; fourth 8. Since supervisory contributions are not included in these data the supervisory level noted as immediate supervisor is the lowest in the hierarchy and the data thus point strongly to the extreme importance of supervision at this level.

The respondents were requested to note whether the supervisor had assigned or simply suggested the task under discussion. Since the majority did not indicate one way or the other, the approximately 2 - 1 ratio of assigned to suggested of those who did so indicate is impossible to interpret.

The remaining individual items do not call for very much comment. It is interesting to note that though there was an opportunity in two places to record the use of work at home (add H

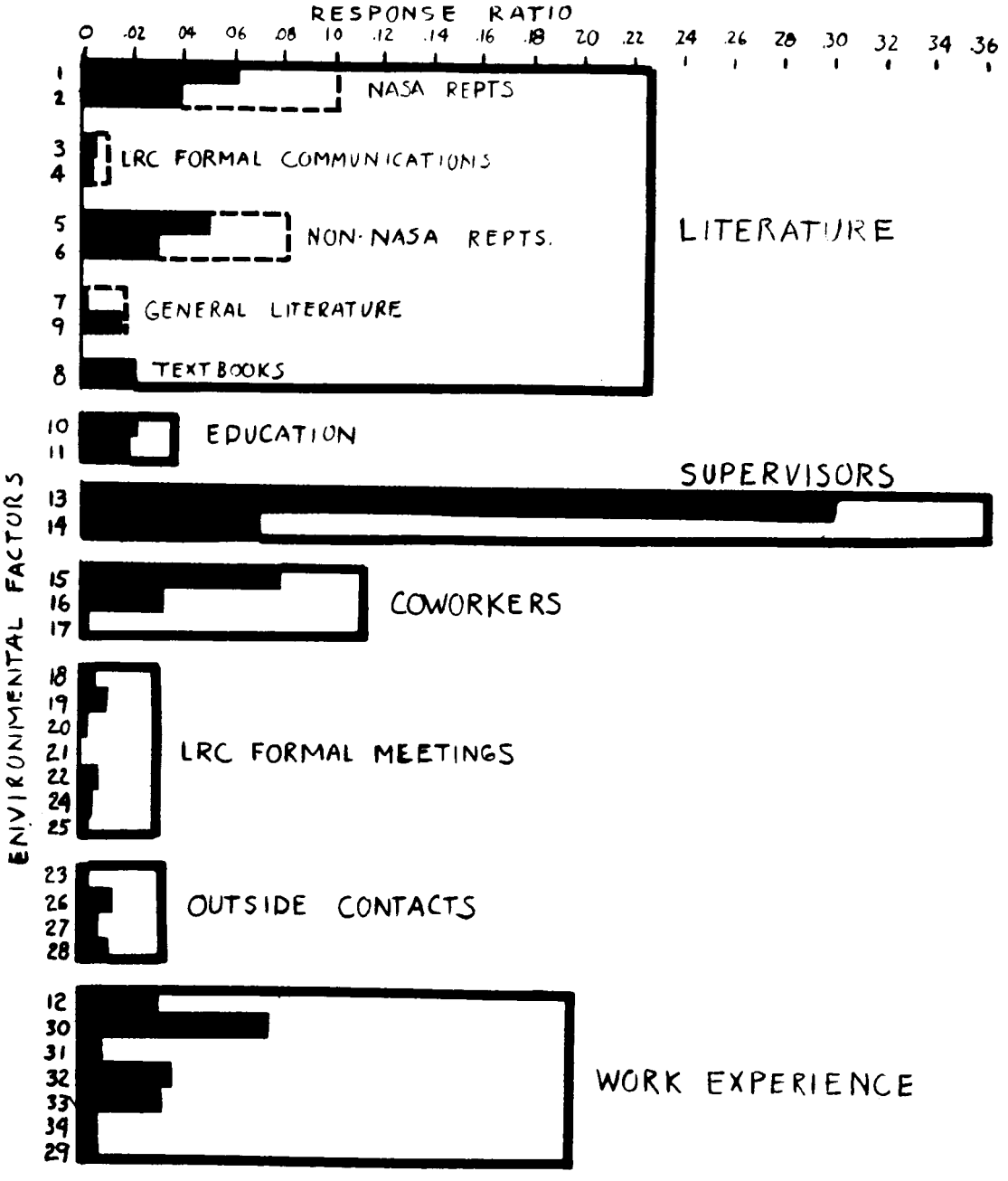


FIG 3 FACTORS AIDING THE CHOICE AND DEFINITION OF PROBLEMS
QUESTION ONE - SUMMARY OF 1482 RESPONSES FROM
157 INDIVIDUALS REPORTING ON 710 CONTRIBUTIONS

after any literature item and factor 34) neither response was used to any extent, thus indicating that taking work home is not felt to have been an important help in choosing or defining problems.

If we now consider the data from the point of view of the classes literature becomes a major factor, as seems reasonable, and the honors are split fairly evenly between NASA and non-NASA reports. Personal experience is naturally enough very important and it is entirely reasonable that "similar research work" leads other items in that category by two to one. The lack of importance of formal meetings and outside contacts is somewhat surprising. The explanation may be in part in the fact that no supervisors are included in these data and it is generally they who are involved in both activities.

Question Two: Solution to Problems

Similar conclusions can be drawn from the answers to question two. Figure 4 which presents the factors which were felt to aid in the solution of the problem, immediately verifies the fact that a different question is being answered by the strong change in mention of supervisors and literature. Aside from this difference however, there is a remarkable similarity between the relative prominence of the other factors - both the groups and the individual items. (However, the Chi-square test does not support this qualitative judgment since it informs us that the differences between the other factors, that is all classes but the literature and supervisor classes, are significant at the .001 level.) The major difference in the other items is the increased influence of education - which is reasonable. However, the response to graduate study is surprisingly low. NASA and LRC in particular have spent a great deal of time and effort

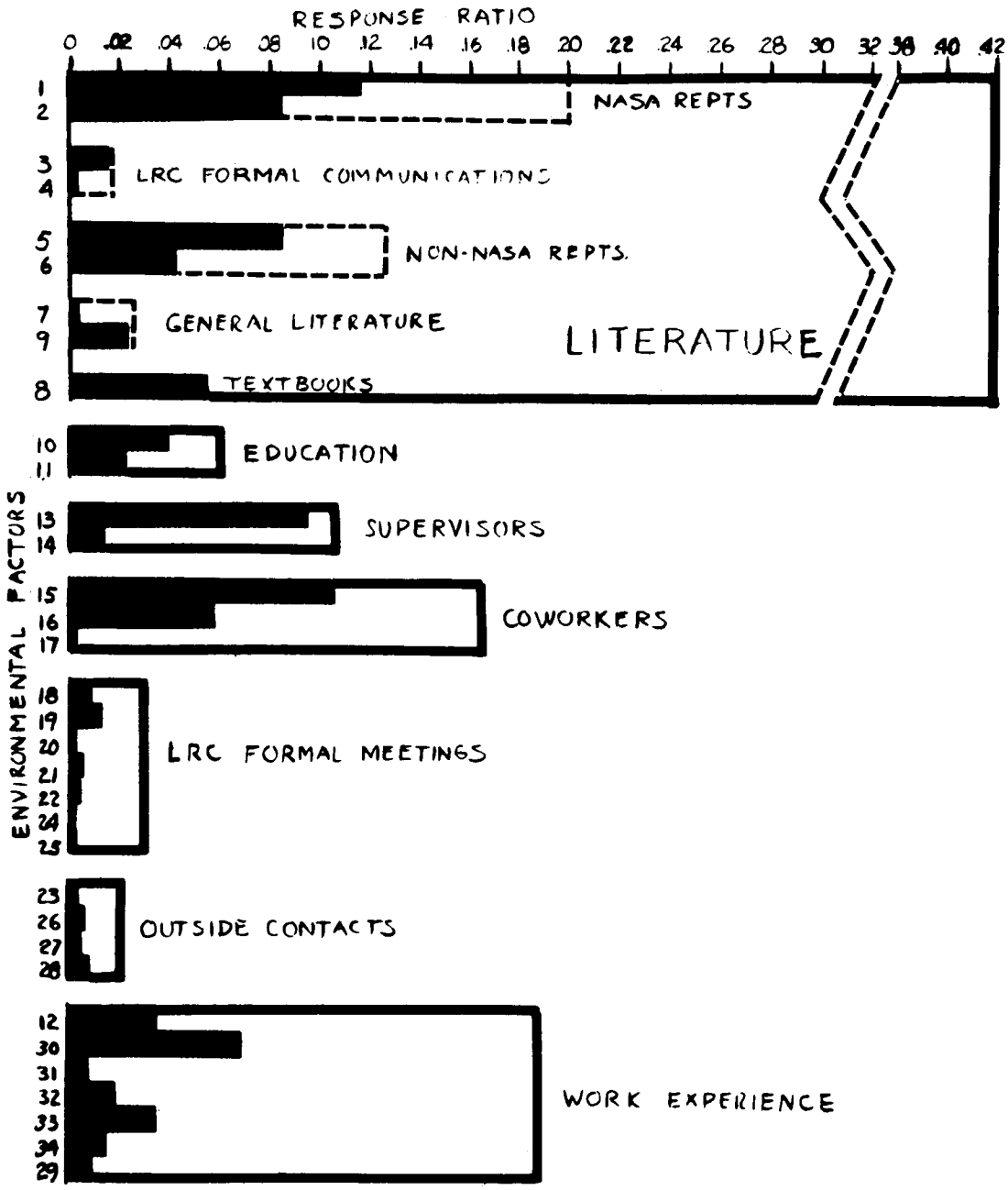


FIG. 4 FACTORS AIDINGS THE SOLUTION OF PROBLEMS QUESTION TWO

SUMMARY OF 2004 RESPONSES FROM 157 INDIVIDUALS

REPORTING ON 710 CONTRIBUTIONS

on graduate programs and they have been well attended. "Outside contacts" is lower for aiding a solution than aiding a choice of a problem and that seems perfectly predictable.

Question Three: Motivational Factors

The third question asked for motivational factors felt to have been the cause of extra effort on the work in question. It drew the fewest responses of the three questions, 1,049 compared to 1,482 and 2,004 for the first and second questions respectively.

Again the general distribution of the factors is not surprising since it shows the strength of professional motivations and this has been established in much previous research notably ref. 8.

Control Factors - Information About the Contributions

The first sheet to be filled in by the respondent was designed to determine characteristics of the respondent at the time of the contribution noted and of the contribution itself. Figure 6 presents the data on the contribution itself and Fig. 7 supplies some information on the age of the respondents at the time the contributions were made.

Figure 6, question A gives an interesting breakdown of the contribution by type of work. Questions B and C were concerned with self evaluations of the originality and usefulness respectively of the contribution. The distributions are quite similar and the percentage giving the highest catagory in each class is exactly the same. The way the data are presented, hides two very interesting facts. First about half the contributions rated in these catagories are rated so in both of them and second, nearly 43% of the respondents indicated that at least one of their contributions was either very useful or very original.

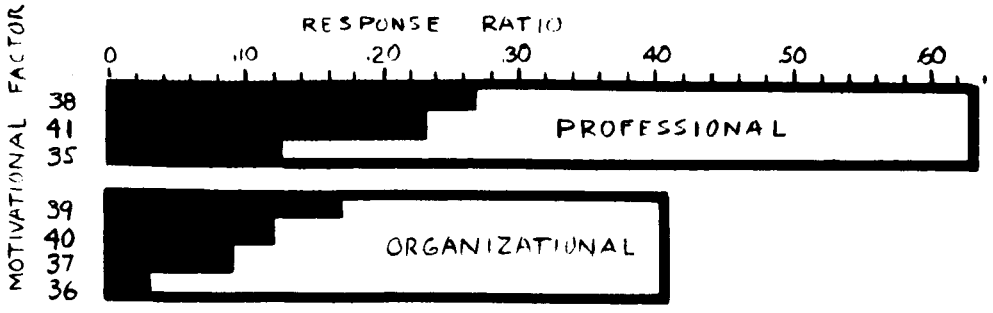


FIG 5 MOTIVATIONAL FACTORS QUESTION 3
SUMMARY OF 1049 RESPONSES FROM 157 INDIVIDUALS REPORTING ON 710 CONTRIBUTIONS

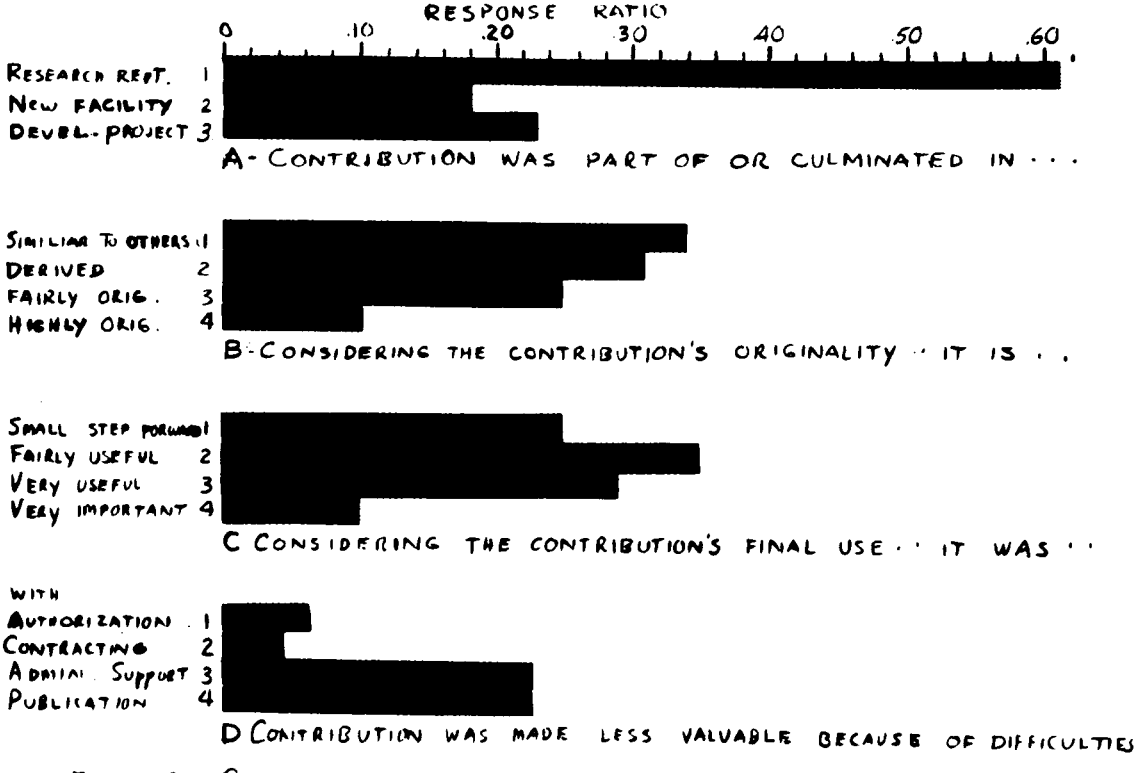


FIG 6 CONTRIBUTION CHARACTERISTICS

These self ratings are very interesting and are examined in more detail in sections dealing with group differences.

Question D received only 400 replies from the 710 contributions - which simply means no difficulties were noted for the other 310 contributions (there were 4 or 5 write-in answers to this question). It is difficult to say whether 56% of ideas considered to be among the researchers best were made less valuable because of organizational problems is a serious or unusual problem without something for comparison. However, it does seem high, especially the high response on publication problems.

Figure 7 presents the ages of the respondents at the time the work was done on their contributions. It is tempting but dangerous to make the data say that research people think their better ideas are produced in the late 20's and early 30's. The temptation is enhanced by the fact that so many of the people interviewed went back to their early careers to choose contributions. Also, if we look at the following figure (Fig. 8) which presents age distributions for the contributions made before and after 1959, we see that the distribution before January 1959 is much more highly skewed than that for work after January 1959. There are of course other reasons than the one noted above to explain this, for example all respondents were forced to go back farther than three years to pick four of their six examples. This bias can be estimated by shifting the after '59 data to the left 2 or 3 years and then comparing the distributions. The dashed curve on the lower part of the figure was obtained by shifting the post '59 data 2 years since not all respondents would be shifting the whole 3 years. There is an unknown bias in the data which would cause skewing because younger people were not restricted to two contributions only. This bias is probably small however.

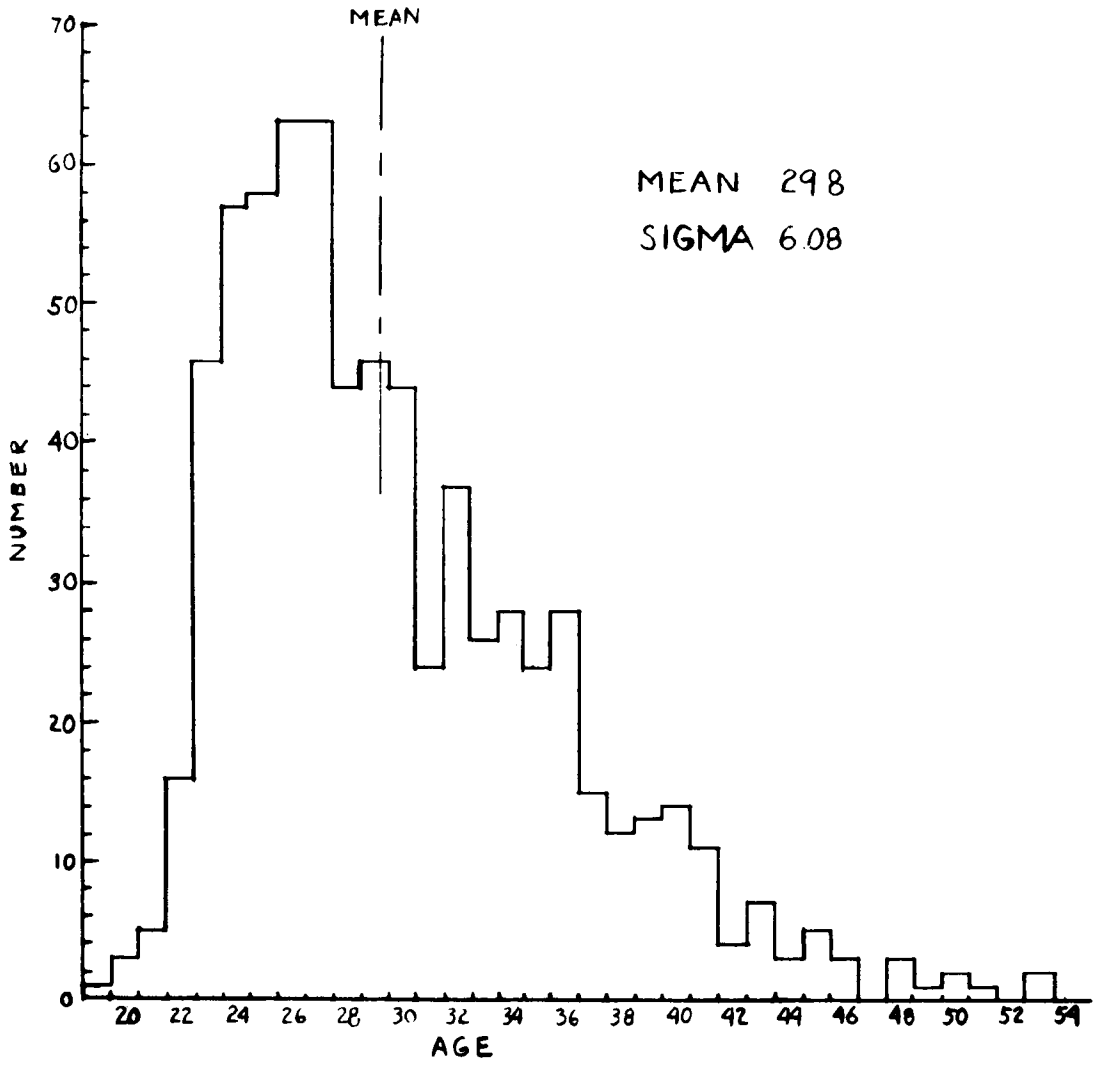
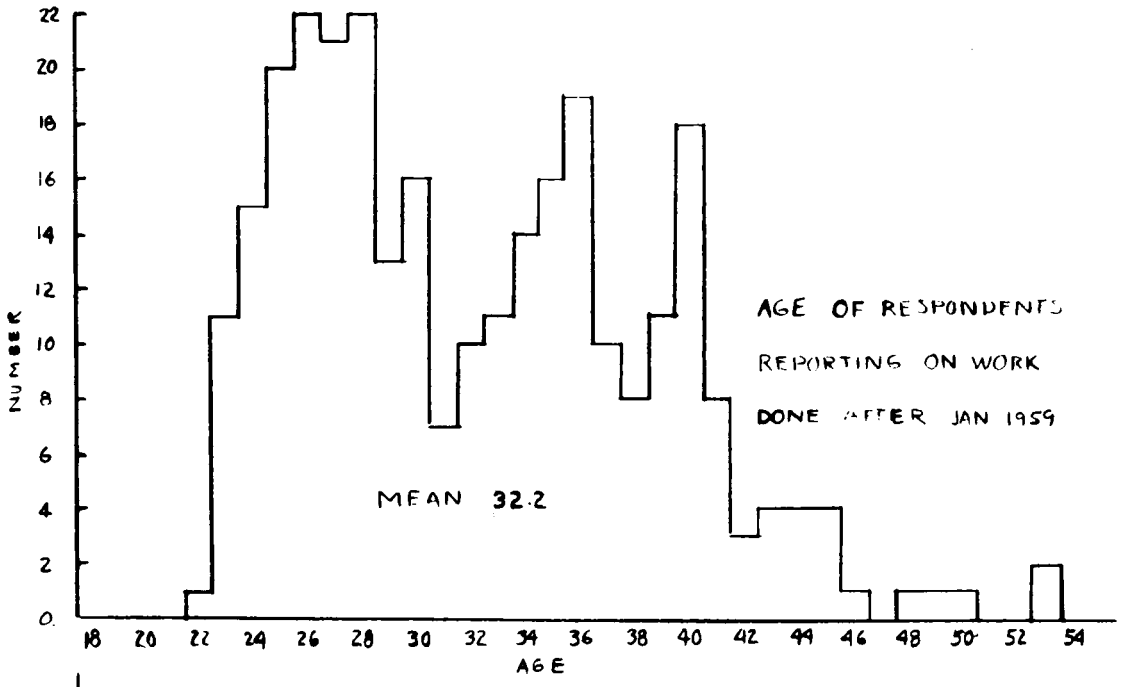


FIG. 7 AGE OF RESPONDENTS AT TIME OF WORK ON CONTRIBUTION



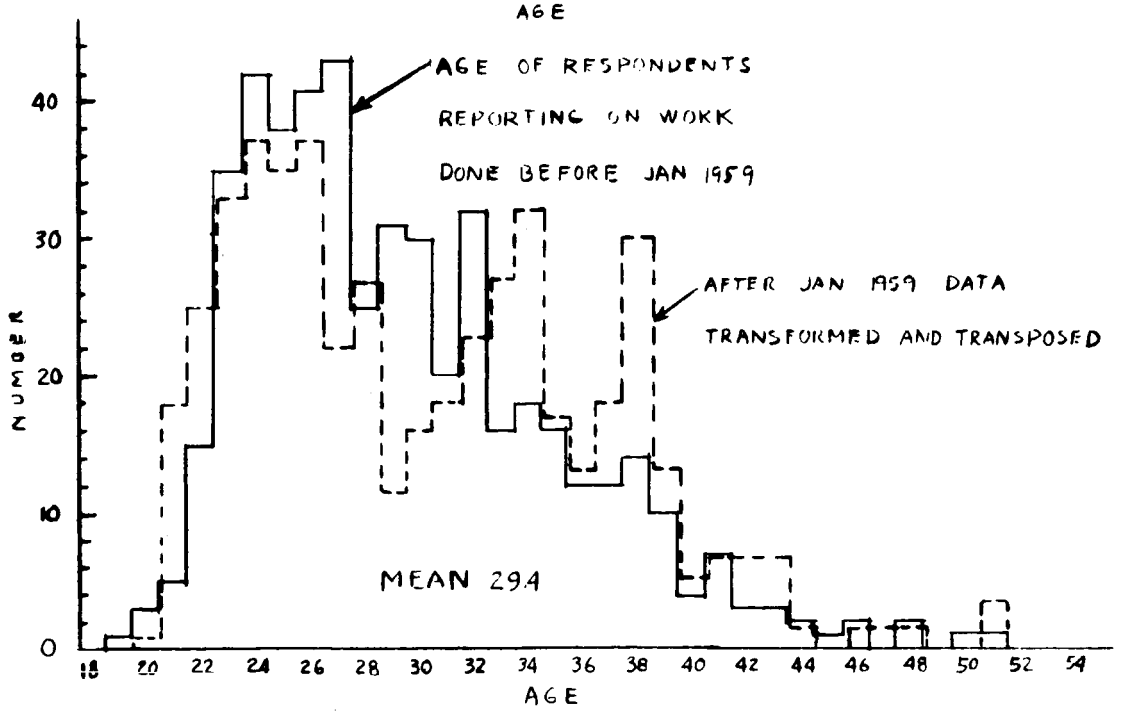


FIG 8 COMPARISON OF AGE DISTRIBUTIONS OF RESPONDENTS
REPORTING ON CONTRIBUTION MADE BEFORE AND AFTER JAN 59

Since the post '59 curve consists of two contributions per person, and the pre '59 data averages nearly three contributions per person, multiplying the post '59 data by one and a half (actually 1.67) will give frequencies with an average value corresponding to the average of the pre '59 data. This has been done in deriving the dashed curve. Now we can say that the shift in distribution represents a definite shift in contribution age. It can be seen immediately that the major shift occurs because the 33, 34, 37, 38 year old people tend to choose contributions in the 27, 29, 30 year range. All in all, it appears as if the skew in the data is more a function of the age distribution of the people interviewed than any strong tendency to say the better contributions were made early in life.

CHAPTER VI

COMPARISON OF SUPERVISORY WITH NON-SUPERVISORY ENVIRONMENTAL FACTORS

All the data discussed up to this point has excluded any contribution made by a supervisor. The returns included a total of 67 contributions made by 21 different supervisors and the results of these data are compared with the results for all the rest of the data in Fig. 9.

Question One: Choice and Definition of Problems

(a) The order of significance is markedly different for the supervisors. Work experience is strongly in first place and outside contacts and formal meetings have significantly more emphasis. These differences are reasonable since the supervisors are the group with the widest experience and their duties naturally lead to a predominance in the outside contact and formal meetings areas.

(b) The fairly low ranking of supervisors as an aid in the choice of problem indicates that the major source of laboratory ideas are located somewhere in this group, though the higher management levels are not without influence. Of the 67 supervision contributions analyzed, over half (35) came from the section head level and another twenty (20) from the group leader level* so that

* See pg. 25

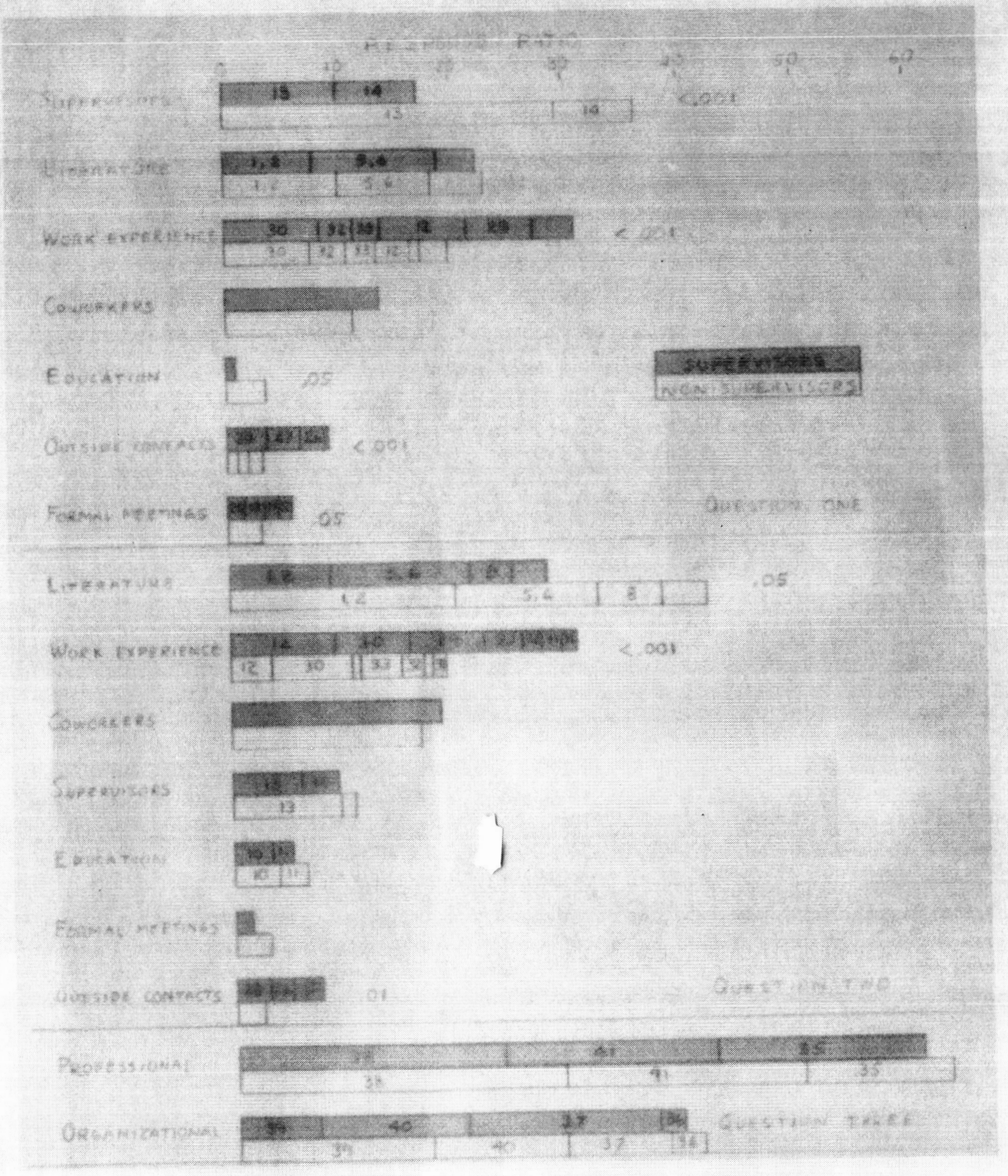


FIG 9 COMPARISON OF ENVIRONMENTAL FACTORS AFFECTING SUPERVISORS AND NON SUPERVISORS

this sample represents the lowest levels of management.

(c) The significant (Chi-square better than .05 level) differences between the 11 higher supervisor contributions and the 55 lower are noted on the list below:

	High	Low
Co-workers	.387	.087
Personal Experience	.097	.352
Literature	.064	.254

The higher supervisors obviously were more conscious of getting and refining their ideas from their fellow workers, which is a sign of good management. But the very low emphasis on personal experience is difficult to explain. **

(d) If we examine the work experience of the supervisors (and as noted in (b) this is the lower supervisory group almost entirely) in detail, two items are nearly entirely responsible for the difference noted, (12) and (29). Item (29) "Supervision" is by matter of definition not applicable

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* Section Head is the lowest official supervisory level. Large sections are sometimes divided into groups with assigned leaders. In our sample, all group leaders come from AMPD.

** The fact that the differences were statistically significant when the contribution is used as the unit item masks the effect of the very low number of people making those contributions. (The 11 high supervisor contributions were recorded by 4 people.) This may be an important effect since examination of the data leaves a strong impression that each person tends to favor the same factor items for all of his contributions.

to non-supervisors* but the fact that supervisors found it a fairly noticeable factor indicates the value of such feedback. Item (12) "Knowledge of more than one field" is naturally a result of longer experience, though it is interesting and somewhat contradictory that the higher supervisor group did not mention it at all.

(e) One item was conspicuously absent from the "Outside contact" group: item (23) "Technical society conferences". This is interesting because of the proliferation of such meetings in the last five years and the concern of research management over the time-drain they can cause.

Question Two: Solution to Problems

(a) The differences between supervisor and non-supervisor contributions is not nearly as marked for this question. Work experience and literature exchanged first place and outside contacts was mentioned more frequently by the supervisors. In fact these three items were the only ones for which the differences were statistically significant.

(b) Again items (12) and (29) were the major cause of the increased emphasis on work experience.

(c) The significant differences between the high supervisor group and the low were:

	High	Low
Co-workers	.342	.147
Literature	.053	.340
Supervisor	.210	.068

* See page 27.

The categories of co-workers and literature exhibited the same difference as on question one. Supervisor choice by the high supervisors was significantly more frequent on this question than on question one (and the higher supervisor (14) was chosen 5 times to 3 for the immediate supervisor (13), which does not seem reasonable since one would expect more help from above on picking and defining problems than in solving them. Another difference from question one was the agreement of higher supervisors with their inferiors in the value of their personal experiences.

Question Three: Motivational Factors

(a) In general supervisors showed the same professional motivations as the non-supervisors.

(b) The organizational difference is interesting in that the effect of a chance at promotion (39) varies with administrative position. The supervisors are much less influenced by (39) than the non-supervisors but the effect is reversed when the supervisor class is subdivided into its higher and lower components. The high supervisors mention (39) .148 compared to the low supervisors .051. There seems to be a middle level group who are (for a period at least) satisfied with their organizational status.

(c) It is interesting and perhaps even logical that the officer class is more conscious of intra-organization competition (37) than the enlisted men.

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* The non-supervisor data included some item (29) selections. This may be because a few replies did not indicate what supervisory position was held and thus a few supervisory contributions may be in the non-supervisory data.

CHAPTER VII

COMPARISON OF TWO DIVISIONS

Data were sought from two divisions at LRC because it was felt that the work and personnel were so different in each that a significant difference in the relative importance between environmental factors should result if the test used was capable of giving meaningful answers. The Aerophysics Division is the more "scientific" of the two divisions. Its personnel work on hypersonic aerodynamics, re-entry flow problems, advanced fluid dynamics and plasma physics and on the whole, do less applied and developmental work than their counterparts in AMPD. AMPD works in many of the same areas but tends to work on the experimental rather than theoretical aspects and because of its use of rocket test vehicles does a fair amount of work of an applied or developmental nature. These are the subjective impressions which led to the choice of the two divisions - it is the purpose of this chapter to see if the data supports these impressions.

Control Factor Comparisons

The answers to the four questions (A, B, C, and D) on the control sheet of the questionnaire give us a measure of the type of work done by each division since the questions are about the contributions themselves, not about the environment. As the discussion below indicates the answers do substantiate to a fair degree the

pre-test judgement of the difference between the two divisions. The data are presented on figure 10.

Question A: Type of Work

(a) The fact that Aerophysics personnel choose more work leading to reports and that the AMPD selections were twice as many in the project or development area strongly supports the pre-test impressions.

Questions B & C: Originality and Usefulness

(a) The differences are generally small and the one very large difference, the higher Aerophysics proportion of fairly useful is hard to interpret.

(b) The other interesting difference is the more satisfied stand taken by AMPD as indicated by the higher percentage who thought their contributions rated "highly original" or "very important contribution". This "optimistic" attitude substantiates the data on the supervisory ratings which was discussed in the chapter on the criterion check list.

It is interesting to note that there is no connection between the people who rate their contributions "very original" and "very useful" with the people who are rated by their supervisors in the upper quartile of C or P.

Question D: Problems Causing Delays

(a) The difference exhibited by the two divisions in their choice of delay problem areas probably depends on the difference in work mix - at least the fact that Aerophysics does more work leading to reports would partially explain their feeling that delays in publication had been their most significant problem.

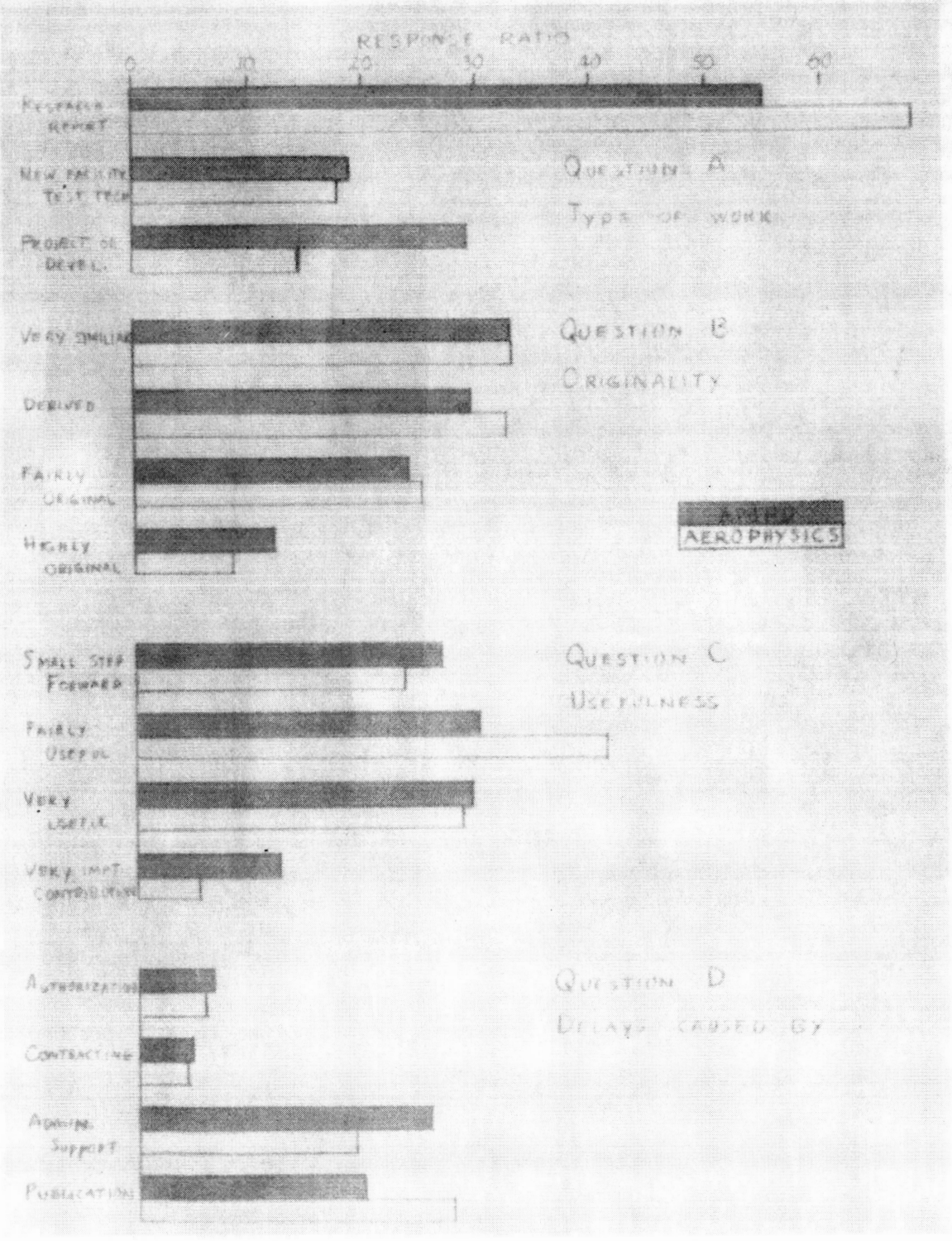

FIG 10 COMPARISON OF CONTROL DATA BETWEEN AEROPHYSICS & AMPD

Environmental Factor Comparisons

Figure 11 presents a comparison between AMPD and Aerophysics of the answers to all three of the questions. The significant differences between AMPD and Aerophysics are:

Question One: Choice and Definition of Problems

(a) AMPD makes much more use of higher supervisors as idea sources.

(b) Aerophysics makes greater use of technical reports, internal and external as a source of ideas, as well as more use of text books. This finding certainly fits its "more scientific" impression.

(c) AMPD emphasize work experience more than Aerophysics for one principal reason. They indicate (32) "Work on development projects" as being a strong contribution while it is almost negligible for Aerophysics. This fits with the preconceived notions.

Question Two: Solution to Problems

(a) Aerophysics again records a greater use of the literature but this time the outside literature causes all of the difference.

(b) Again "Work on a development project" (32) is more important for AMPD but (12) "Knowledge of more than one field" is also significantly more important for AMPD.

(c) Again the use of supervisors is different and Aerophysics still is not noting up-the-line supervisors as a source of help. However, in the use of immediate supervisors they are considerably more active.

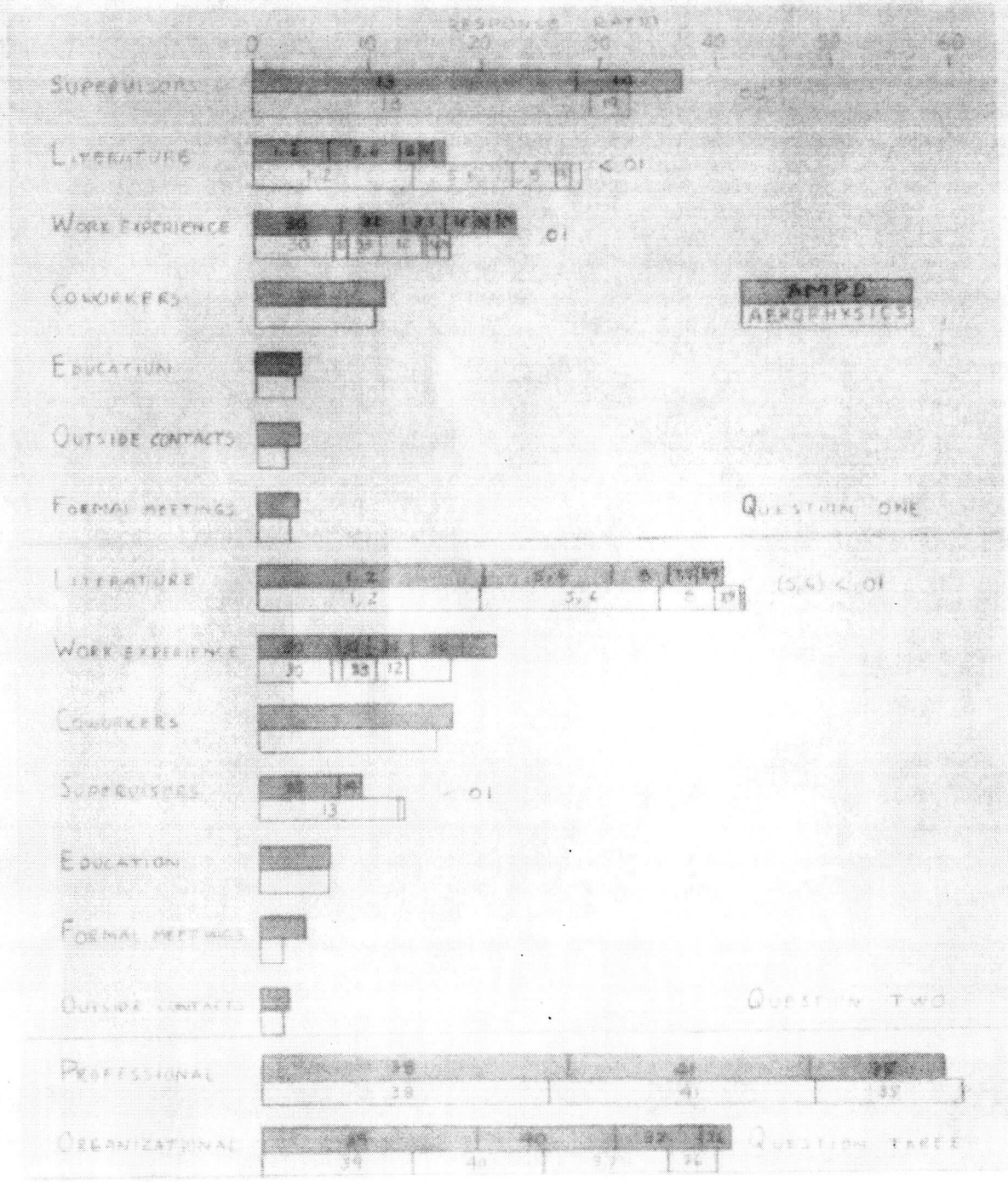

FIG. 11 COMPARISON OF ENVIRONMENTAL FACTORS BETWEEN AEROPHYSICS AND AMPD

Question Three: Motivational Factors

(a) Professionally both groups appear to be motivated in a similar manner but Aerophysics is significantly lower in claiming that chance of promotion spurred them to extra effort. This again fits the "scientific" label.

(b) However, Aerophysics is more conscious of competition as a factor in motivation and are more affected by working on "conference reports".

In general the results seem to confirm the type of difference between the divisions that was predicted.

CHAPTER VIII

COMPARISON OF ENVIRONMENTAL FACTORS BETWEEN HIGH AND LOW PERFORMANCE GROUPS

The check list results described in Chapter Three were used to separate the respondents of each division into a high and a low performance group. Because of the high correlation of the three scores, it was decided to use only one as a criteria. The C scale was developed as a measure of creativity and was chosen because it is that characteristic that should differentiate most highly the factors supporting the production of ideas. Because of the differences between the two divisions in the mean values of the C scores it was necessary to treat each division separately. Thus the high and low groups were obtained by taking the upper and lower C quartiles for each division. The data are also compared on this separate basis and are presented in figures 12a and 12b. Table III below presents the number of responses included in the high and low performance groups.

	# People In Quartile	# Responses Upper Quartile			# Responses Lower Quartile		
		Ques. 1	Ques. 2	Ques. 3	Ques. 1	Ques. 2	Ques. 3
Aerophysics	16	166	185	112	148	205	118
AMPD	23	221	287	189	225	311	165

Table III: Size of Sample of High and Low Performance Group

Question One: Choice and Definition of Problems

(a) The most striking aspect of the data of question one are the strong differences between Aerophysics' upper and lower quartiles, (4 groups significant) and the nearly complete lack of difference in the AMPD data (only one group difference significant).

(b) The differences exhibited by Aerophysics are just those one would predict from the depths of one's armchair. Certainly the more creative, original people will depend for their ideas less on their supervisors, more on their own search of the literature, and less on their fellow workers. The armchair prognosticator would probably have missed the very high use of the formal meeting group by the creative quartile and even post data analysis cannot explain it.

(c) AMPD's lack of differentiation is hard to explain in the light of Aerophysics' performance. However, it must be remembered that the criterion used to separate the two groups was essentially a subjective type of rating and that the two divisions apparently differed considerably in their scoring.

Question Two: Solutions to Problems

(a) The question two data reverse our (a) comment to question one data; that is, Aerophysics exhibites no significant differences and AMPD two. The explanation shoe could be on the same foot however, (i.e., AMPD's data needs the explanation) if it were rationalized that choosing and defining problems were essentially creative type tasks and thus people different in creativity would react to those tasks in very different ways. Similarly solving problems requires

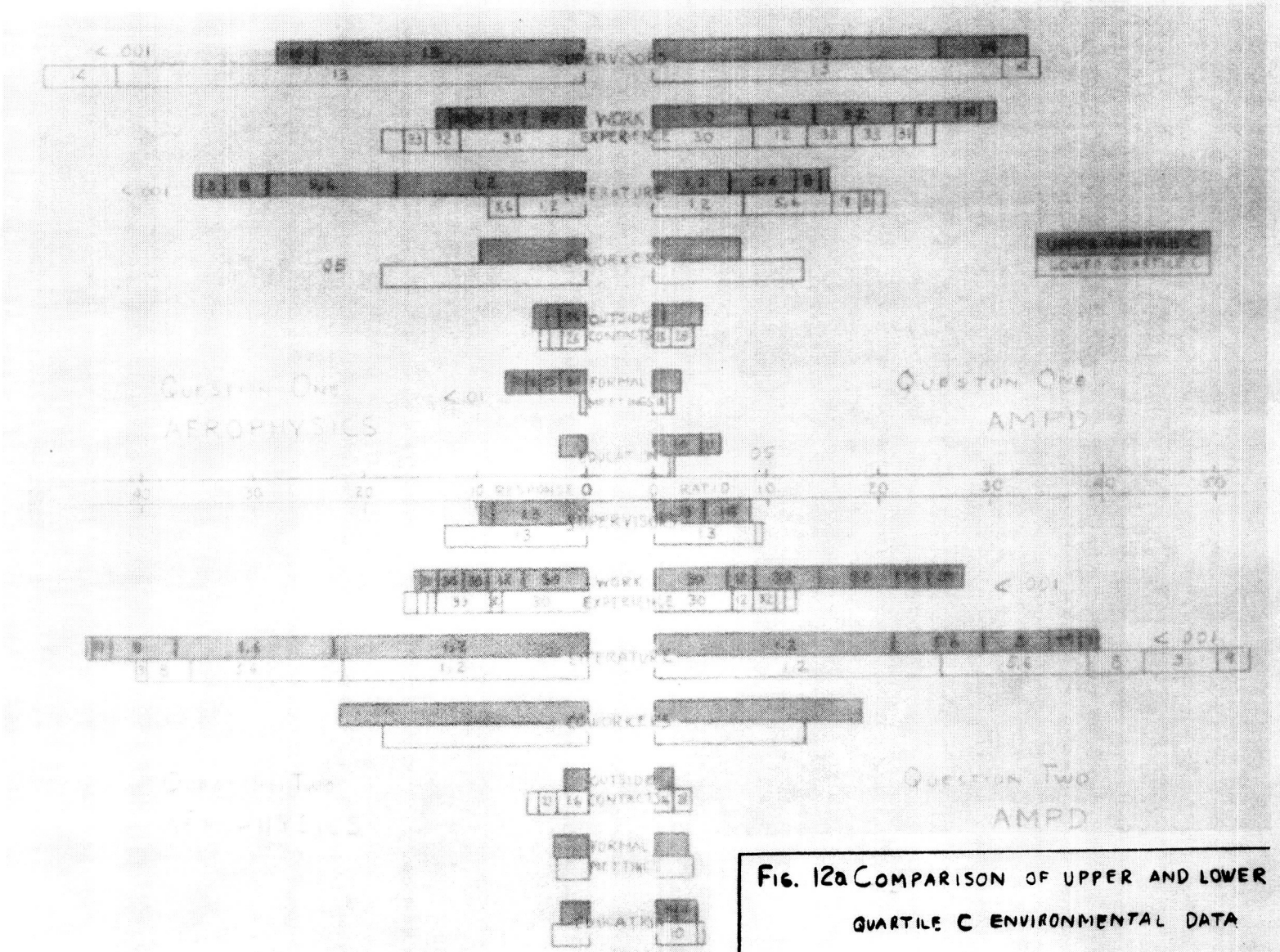

FIG. 12a COMPARISON OF UPPER AND LOWER QUARTILE C ENVIRONMENTAL DATA

information and skill but not necessarily large amounts of creativity and thus separation by a creativity criterion would not be expected to produce different uses of the environment.

(b) It is difficult to explain why the less creative AMPD group found literature more helpful than the more creative. The inclusion of item number (3) in such a large proportion is worthy of note. In fact this group chose number (3) 18 times which can be compared with the total for the entire AMPD sample of 25 and the total for every return of 29. Part of this somewhat unusual aggregation may be related to a type of data bias (noted in the footnote on page 25) which is due to respondents tendency to choose the same factors for all his contributions, since six of the eighteen choices in this case were made by one respondent.

(c) The differences in work experience between the AMPD quartiles is much more amenable to rationalization. The climate of the division is such that the better people are more likely to be involved in development type of work (32). The reason for the appearance of work at home (34) may simply be that creative people tend to be more involved in their work than others - note that in both divisions it is much higher for the higher quartile group. Twenty nine (29) may be important due to the fair number of group leaders in AMPD who may not have considered that position a supervisory one for the purpose of the questionnaire (and it was omitted from the instructions on the questionnaire). The importance of free time (33), seems a natural one for creative people to appreciate and use more than their less talented fellows. Of course the Aerophysics data apparently reverses

this position but it is not statistically significant and can thus be ignored.

Question Three: Motivational Factors

Figure 12 below presents the responses to question three. None of the differences are statistically significant at the P = .05 level. This lack of significant difference is interesting in the light of the results of ref. 8 which showed that the more creative group was consistently more affected by environmental factors labelled professional than the less creative who were more conscious of the importance of non-professional items. Some of the items on their two lists are very similar to items used in the present study, i.e., competitive position of the company in its industry, prospects for future salary increase, opportunity to make real contribution to your profession and freedom to do work interesting to you. Because of this similarity and because the total sample in the present study seemingly agreed with the ref. 8 results, it is of interest that this sub-group did not. (The relationships in Aerophysics though not statistically significant compare qualitatively to ref. 8 results.) This is an indication of the danger of comparing different groups obtained with different (though named the same) criteria.

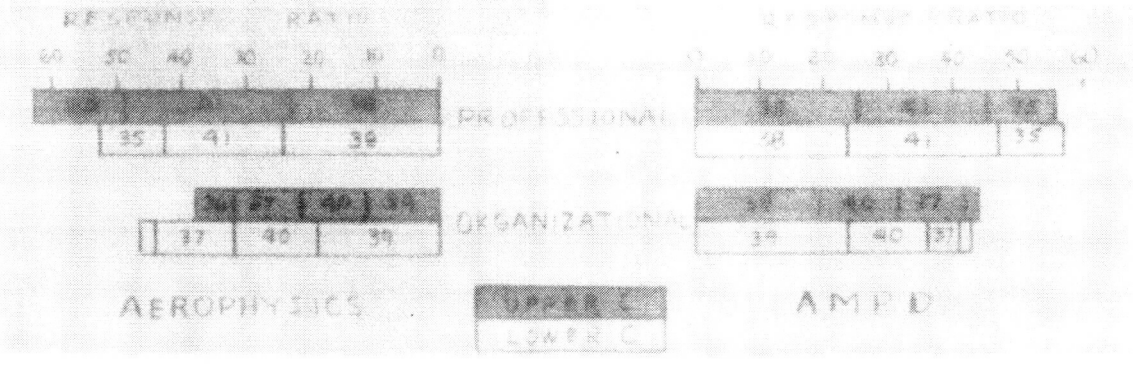

FIG. 12b COMPARISON OF UPPER AND LOWER QUARTILE C MOTIVATIONAL DATA

CHAPTER IX

ENVIRONMENTAL FACTORS AFFECTING THE CHOICE AND DEFINITION OF THE "HIGHLY ORIGINAL" CONTRIBUTIONS

It was pointed out in Chapter V that a fair proportion of the respondents judged at least one of their contributions to meet the criteria of "Highly original - new techniques used in novel ways". (Question B on questionnaire control sheet.) Since original ideas are supposedly the ultimate purpose of a research laboratory it is of interest to compare the environmental factors affecting their conception and refinement with the factors noted for the less original contributions. Such a comparison could best be made between the contributions judged "highly original" and those judged "very similar to work done elsewhere". However, the number of the "highly original" contributions is a small proportion of the total number of contributions (10%) and a comparison with the total non-supervisory population serves the purpose nearly as well.

It was noted in Chapter VII that no larger a proportion of those who judged at least one of their contributions "highly original" were considered "creative" by the supervisors (upper C quartile) than the population as a whole. Because of this, it is of interest to ask whether there is any relation between the environmental factors used by a "creative" person and those used by the average researcher to obtain and define problems he himself feels are "highly original" or creative.

Such a comparison is made in fig. 13. In addition to the combined results of the upper C quartile groups from each division the data for the supervisors has been added since it is similar in many items to both of the other groups. The data for the total non-supervisory sample is indicated by the dark vertical line extending across all three bars. The significance notations (P = .01, etc.) refer to the relationship between the item noted and the total non-supervisory sample.

All three groups differ in important and similar ways from the total sample. All emphasize work experience and deemphasize the supervisor as a source of ideas. If the work experience group is examined in detail, some interesting differences appear. The "highly original contribution" group rate free time (33), work on a development project (32), and work at home(34) more highly than any of the other groups by a wide margin. In fact this group is really the only one that has noted work at home as a significant item. (It was mentioned 11 times in the total non-supervisory sample. The "highly original contribution" group contained 8 of those responses.)

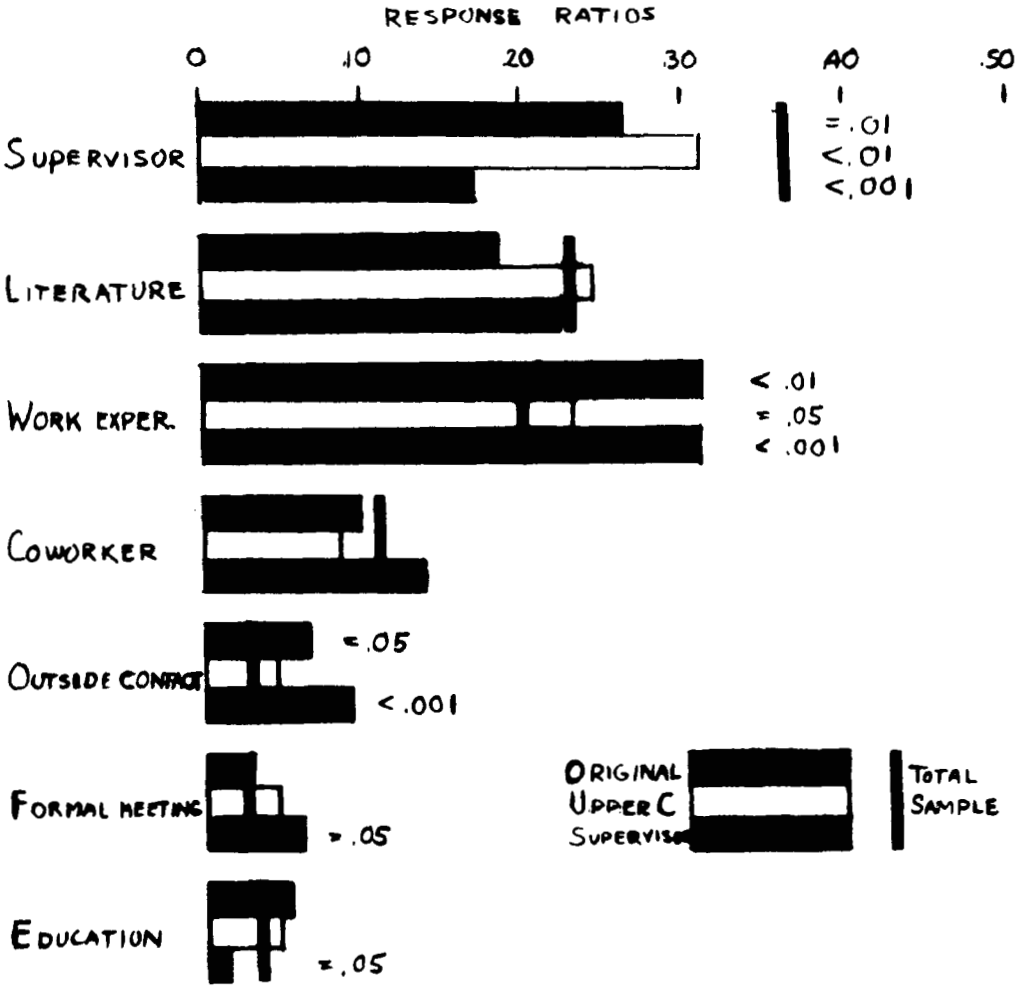

FIG 13 COMPARISON OF ENVIRONMENTAL FACTORS AFFECTING THE CHOICE OF PROBLEM (QUESTION ONE) FOR THREE SPECIAL GROUPS

CHAPTER X

SUMMARY OF RESULTS

The main purpose of this study was the determination of the relative importance of laboratory environmental factors in the selection, solution and motivation of problems. The previous chapters have examined the responses to each of the questions in detail and the relation of the response patterns to various sub-groups taken from the total sample. The present chapter summarizes all the answers to each question. As an aid to the summary, figures 14, 15, and 16 have been prepared presenting all the responses to each question in a single figure.

Question One: Choice and Definition of Problems

(1) Supervisor most important single influence: The majority of the groups concurred that the supervisor was the most important influence in the choice and definition of the problems they chose as being their own best contributions. As noted in Chapter V the respondents strong tendency to indicate the supervisor as first choice causes the averaging of the first four choices with equal weights to mask the full importance of the supervisor's influence. Note that the supervisory levels indicated by the majority of the respondents are the lowest in the organization. The fact that the responses of supervisors at these low levels did not emphasize strongly the importance of their supervisors ,

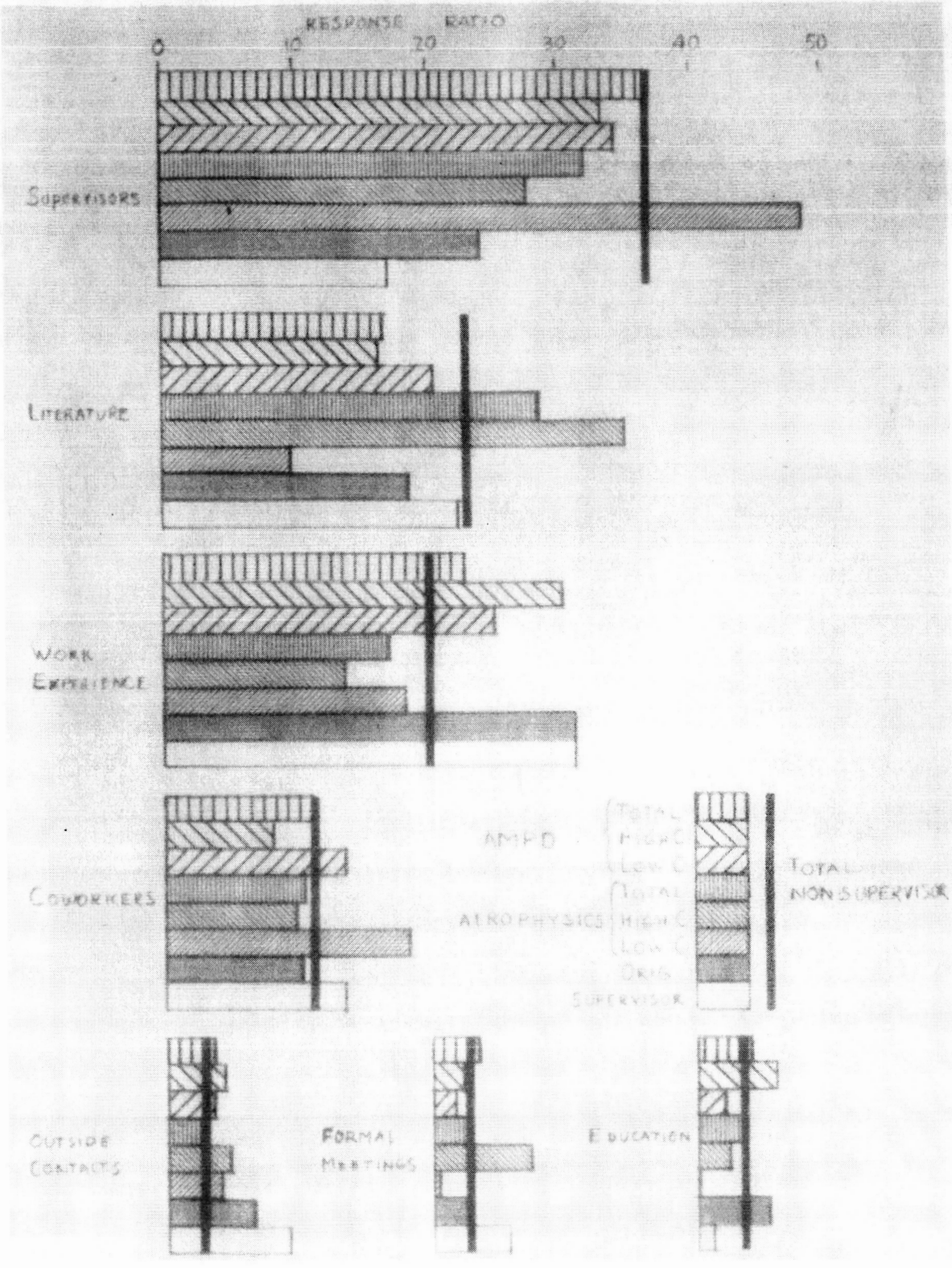

FIG 14 SUMMARY OF ALL RESPONSES TO QUESTION ONE

FACTORS AIDING THE CHOICE AND DEFINITION OF PROBLEMS

indicates that problems are being chosen and defined fairly low in the organization.

(2) The importance of literature and work experience is a strong function of organizational group: In the over-all sense, these two classes of environmental factors are just about equally important. However, the two divisions treat them quite differently even though the general area in which they work is quite similar. Aerophysics' greater use of literature included more use of both NASA and non NASA reports and text books. AMPD's greater emphasis on work experience consisted almost entirely of work on or for a development project, an item mentioned hardly at all by Aerophysics.

(3) Work experience of prime importance to supervisors: The most important class of environmental factors cited by supervisors is work experience. The most important items in the class are similar research work (which was the most cited work experience item for all the groups), knowledge of more than one field, and aiding of subordinates. The latter two items are responsible for the difference between the supervisory response and that of the non-supervisory group. Knowledge of more than one field comes naturally as a result of experience but it is interesting to see that supervisors are conscious of the use of subordinates in choosing and defining their problems.

The similarity in response of the original contribution group to the supervisor group hides the different stress on the individual items. Work on a development project and free time were two significant items which were cited by

the original contribution group but hardly at all by the supervisors.

(4) Effects of other factors on the choice and definition of problems: The responses to the other three major categories were universally low and generally consistent in all the sub-groups. The higher reaction of the supervisors to outside contacts and to formal meetings is consistent with the supervisors status and use in the organization.

Perhaps the most significant thing about these three catagories is the low significance of some of the items within them. The graduate study program at LRC is well attended and yet this catagory received even less mention than pre-employment schooling. Outside contacts in the form of technical conferences of professional societies are much sought after by the engineers and yet received next to no notice as a source of ideas. Formal conferences inside LRC of various types were designed for the purpose of bringing together workers in various fields with the hope of achieving some cross fertilization and generally are well attended. Thus the nearly zero effect of these items is surprising.

Question Two: Solution to Problems

(1) Literature is the most important aid to solution of problems: It is certainly not hard to accept the data's indication of the great importance of the literature in the solution of problems. The sub-groups are unusually consistent in their individual ratings on this factor. The lower emphasis by the supervisors is naturally a result of the increased administrative

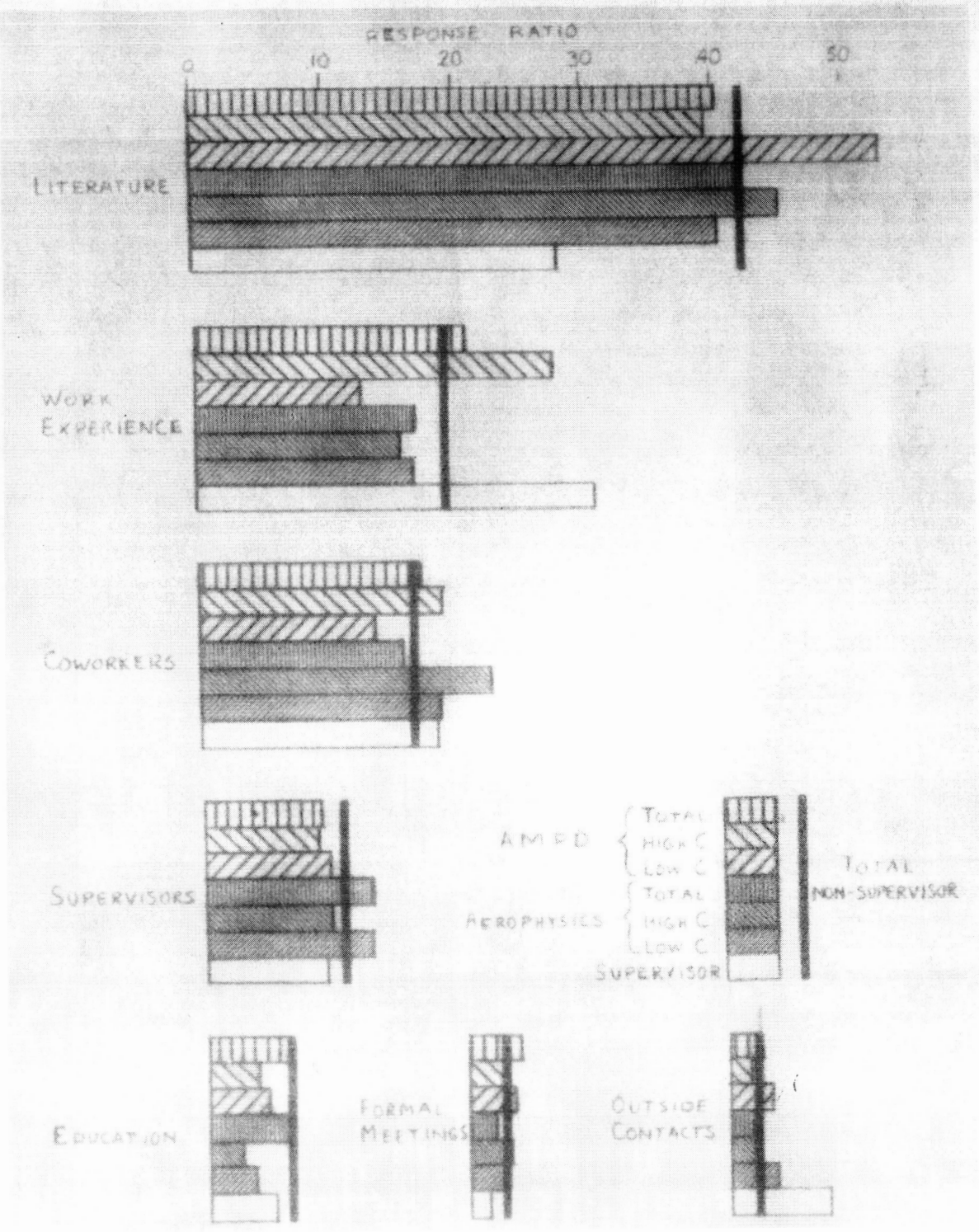

FIG. 15 SUMMARY OF ALL RESPONSES TO QUESTION TWO

FACTORS AIDING THE SOLUTION TO PROBLEMS

duties pressed on them by their position.

The ratio of inside to outside technical information is about one and a half to one and these two categories dominate the literature group although text books are also an appreciably appreciated item.

(2) Supervisors find work experience their most important factor in solving problems: As with question one, the supervisors are almost forced to emphasize this category because of their administrative position. The items causing their high response are knowledge of more than one field and supervision of subordinates. They are expected to and do, use their broader experience and the people under them to solve as well as choose their problems.

(3) Divisions exhibit little difference in their use of environment to solve problems: In contrast to their different environmental approach to the choosing of problems, the two divisions are remarkably similar in their responses concerning the solving of problems.

(4) Supervisors not important factors in solution of problems: In strong contrast to the dependance on the supervisor for the choice of problems the data show that they are of fairly minor importance in the solution of problems. This is certainly as it should be in a research laboratory where the workers are all professionals and expected to operate as individuals.

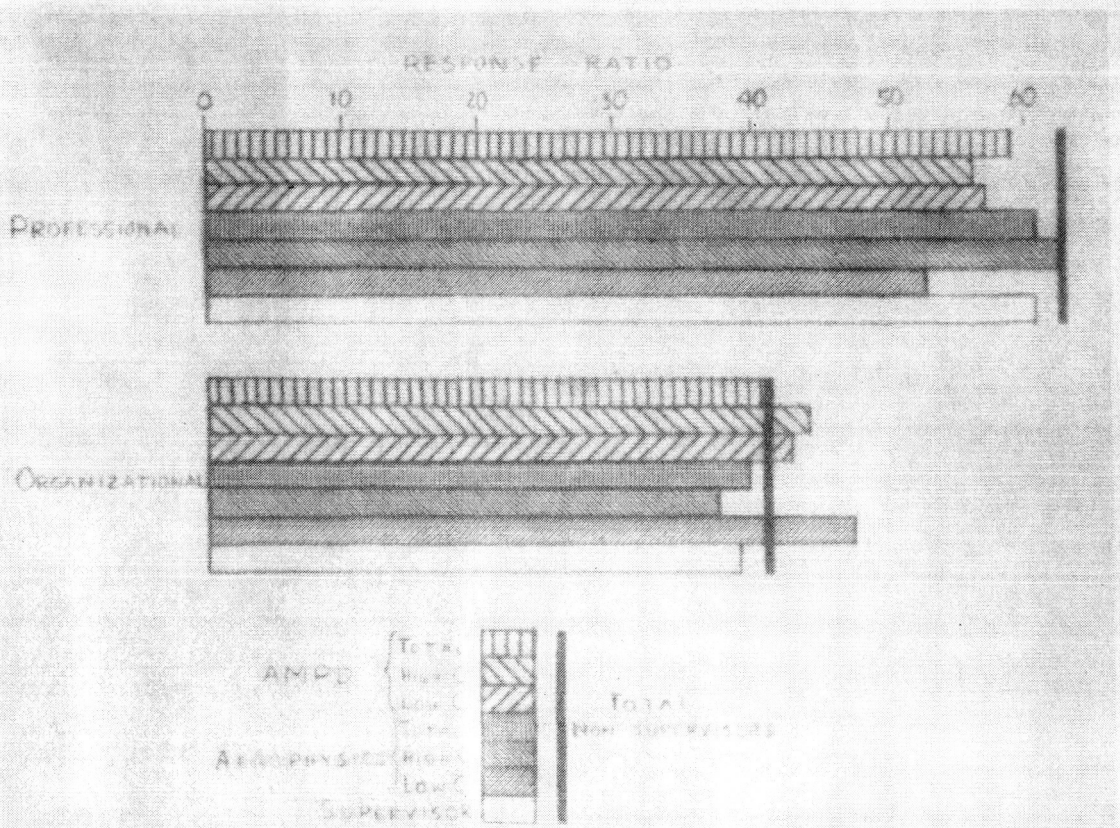

FIG 16 SUMMARY OF ALL RESPONSES TO QUESTION THREE
MOTIVATIONAL FACTORS

Question Three: Motivational Factors

(1) Professional factors more important than organizational motivations: This result is not surprising and has been noted before in other survey work (ref. 8). The greater emphasis on internal values seems to be a characteristic of the professional class in many different fields and there were no significant differences in responses to the three items making up this category between any of the sub-groups investigated.

(2) Organizational motivation affected by group membership: Although the total organization response of the various sub-groups was fairly consistent, some differences between their choice of specific items are interesting. The supervisors were very conscious of competition with other divisions, people, techniques, or laboratories as a motivating factor. They undoubtedly have greater identification with their organizational unit than do non-supervisory personnel. The lower supervisors deemphasized chance of promotion, while the few higher supervisors responding emphasized it as much as the non-supervisory class. Between the divisions, AMPD noted chance of promotion more often than Aerophysics while Aerophysics emphasized the competitive motivation.

CHAPTER XI

IMPLICATIONS

For the Management Analyst

One of the main roadblocks to useful work in the field of research management analysis is the wide range of application of the word research. Not only does it vary with the scientific discipline in which it is found, but within any one science there are countless gradations of activity all labeled research, with and without various modifiers such as basic, applied and developmental. Because of this wide variety of activity subsumed under the title of research it is certain that there are very many "ideal" environments.

Since the present study was made at one laboratory only, it would be very dangerous to attempt to draw wide ranging conclusions from its data. However, the data do provide a quantitative description of the relative merits of environmental factors in one laboratory on what are probably researches' most common denominators - the production of new concepts and the solution of unique problems. The most significant aspect of the data is its numerical quality. This feature of the method and its results may lead to the ability to describe the type and kind of research being done by index numbers based on the manner in which the researchers are using their environment to accomplish the goals of their laboratory.

The present study was not designed with this goal in mind, but the data obtained allow a provocative illustration of what can be done in this area. As was noted in Chapter VII the two divisions at LRC from which the data were obtained had different attitude climates though their fields of interests were quite similar. The data seem to corroborate the pre-test feeling that one division was more "scientifically" oriented than the other. The differences in the use of environmental factors by the two divisions have been presented by bar chart comparisons. Since there are seven major environmental classes and 34 minor ones the comparison becomes quite complex. A little imagination allows the data to be manipulated in ways which can make the difference between the divisions more obvious and perhaps more meaningful.

If it is hypothesized that a more "scientific" orientation implies a greater dependence on a scientific discipline and that this in turn implies a greater dependence on the literature as a source of ideas than the less scientifically oriented or more applied work, then a comparison of the percentage of the total responses indicating literature would serve as an index of scientific orientation. It is equally reasonable to state that the more application oriented workers would depend more on the factors in their work experience * for new ideas than the more traditionally oriented group. This can be added as an inverse relationship and an index of scientific

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* Work experience is defined as it is used in the present investigation. This includes similar research work (30), work on facility design (31), work on or for a development project (32), free time (33), work at home (34), knowledge of more than one field (12) and supervison of subordinates (29). The statement is reasonable if (33) and (34) are excluded and in fact these did receive little notice in the responses.

orientation be developed by taking the ratio of literature to work experience responses. The table below illustrates the results for the two divisions and their upper and lower performance groups.

	Question One: Choice of Problem		Question Two: Solution of Problem	
	AMPD	Aerophysics	AMPD	Aerophysics
Total	.74	1.65	1.9	2.46
High Performance	.54	1.95	1.43	2.8
Low Performance	.80	.71	4.4	2.4

Table IV: Scientific Orientation Index

The comparison of the index numbers shows the strong difference between the two divisions in their answers to both questions. The high and low performance groups were chosen by supervisors in each division who it can be assumed were very conscious of the value climate of their own division and thus tended to rate as high those who fit their conception of the proper attitude for the division and rate low those who did not. This can explain the fact that the high performance group is lower on the scientific orientation scale for AMPD, which as a whole deemphasizes this orientation in comparison with Aerophysics, and the low performance group is higher than the division average. Similarly with Aerophysics, the high performance group accentuates the division's obvious trend in the direction of high scientific orientation while the lower rated group acts like the members of the other division. Such results emphasize the circular nature of self-rating scales.

The use of the index number allows interesting comparisons of the results from the two questions. For example, it seems that the difference in division climate operates much more stongly in the area of choosing and defining problems to be worked on than in the area of solving them. If the scale used were in some sense an absolute one (which of course it is not) then it could be said that both divisions rated high in their use of the scientific approach in solving the problems they chose so differently.

One more example will help make the flexibility of the index concept clear. Research of all kinds places high value on individual initiative and self-dependence. Organizations of all kinds value these characteristics and generally promote the people who exhibit them. An index of initiative, or self-dependence can be contructed from the envrionmental classes used in this study be adding the responses for literature and work experience and dividing the resulting sum by the sum of co-worker and supervisor responses. The rational is that the first two involve only the individual while the latter two involve help of some sort from another person. The table below presents some examples of such an index number obtained from the data of the present study.

	Question One: Choice of Problem	Question Two: Solution of Problem
Supervisors	1.74	2.17
AMPD Total	.81	2.3
High Performance	1.10	2.5
Low Performance	.94	2.66
Aerophysics Total	1.08	2.10
High Performance	1.40	1.90
Low Performance	.82	1.95

Table V: Initiative Index

Supervisors, as could readily be expected, show the highest amount of initiative in connection with the choice of problem. They are surprisingly not the highest for question two. It may well be that none of the indexes for question two are significantly different from one another which would suggest that problem solving is handled in pretty much the same way by all groups and ranks. (The supervisors in this sample are very much at the working level - see note Chapter VI). The high and low performance groups in each division have related high and low initiative indexes which are consistent with the value placed on initiative in this environment.

There are no doubt many objections which could be raised about the definition of the indexes the rationalization of their meaning and about the interpretation of the results of the two examples. However, these are examples only and are taken from test items not originally conceived with this purpose in mind. The results do appear reasonable enough to make very exciting the possibility of devising and using such an index method for capturing in numbers the hazy generalizations which now are used to describe the myriad forms of research activity and research environment.

For the Research Administrator

The data from the questionnaire produced a picture of the environmental patterns affecting problem choice and solution which is on the whole self-consistent and certainly not too different from what qualitative observation would assume it to be. This means that the undoubted limitations of the technique - its semantic problems, etc. - have not caused any appreciable error in the results. There is, however, one aspect of the results which needs considerable caution in its interpretation.

There are quite a few items which are conspicuous by their lack of mention in the responses. Among these are items such as graduate training, outside contacts, and formal meetings. These are items designed specifically for greater internal and external communication of ideas and transmittal of professional skills. It is extremely hard to believe that the respondents are saying that these items have been almost useless as aids to the productive life of the laboratory. Perhaps they must be interpreted as overhead items whose effects on the production process are too diffuse to be noticed even by the workers themselves. *

The data also have positive implications for the research administrator. Three of the sub-groups analyzed, the supervisors, the high C quartiles and the group who chooses at least one of their contributions as being highly original can be considered the better researchers in an over-all sense. Thus, it would be reasonable to identify the ways in which their use of the laboratory environment differed from that of the sample as a whole with the hope that examination of the differences would suggest those aspects of the environment needing increased emphasis.

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* One respondent states this interpretation problem when he says, "A number of environmental factors that I consider absolutely essential to the proper functioning of this research center have not been noted because a strong, clear contribution .....was not immediately evident as I filled out the questionnaire." Another respondent noted, ".....freedom to travel, and freedom of communication around the Research Center are... already among (LRC's) most favorable characteristics." This latter comment leaves the impression that the present usage of such items is satisfactory.

The replies from these three groups to question one (choice and definitions of problems) are compared with the total non-supervisory sample in Figure 13. Work experience stands out as the environmental class which these groups found exceptionally significant in the selection of their problems. It is necessary to examine the individual items which were of consequence to obtain material for specific recommendations. Three items account for the major differences -- 12, 32, and 33.

Item 12, knowledge of more than one field, was noted by both the supervisors and the original group about two and a half times as often as the total sample. This is a very interesting fact in these days of increasingly rigid specialization. Fortunately, this is a factor which is open to a reasonable amount of control by management since there are several ways of encouraging researchers to broaden their field of activity.

Factor 32, work on or for a development project, and Factor 33, free time, were chosen significantly more often than the total sample by both the high C* and original groups. In one sense, these two factors are opposites since work on a development project means working under time pressure and fairly close direction with little or no time to explore by-ways on one's own initiative. The fact that they appear together may indicate that the work mixture has been such that the researchers have been involved occasionally in developmental work without being swallowed up by it. The data do not

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* Emphasis on both these factors is due almost entirely to AMPD responses. Aerophysics high-low C difference in work experience was not significant, but what there was of it was opposite to AMPD's difference.

indicate what a good work mix might be, but do give encouragement that good mixes have been found by individuals in the past, and therefore that deliberate planning along these lines might prove fruitful.

Outside contacts was one of the categories noted above that received surprisingly little notice as a significant factor in the choice of problems. The over-all impression must be modified when the data are compared between groups, because two of our "better" groups made significantly greater use of this category and the third tended in the same direction. Item 27, visits to industry or universities, was strongly noted by all three groups and Item 28, personal acquaintances and communication with outside experts was emphasized by the supervisors and the original group. While from the total picture, outside contacts are of minor importance, the fact that the "better" groups made more use of several items in this category suggests that management give continued attention to this area.

Another facet of the data that may prove useful for management is the large difference between the two divisions. One example of a practical decision might be based on the significant difference between the two divisions' use of the library facilities. Other things being equal (though, of course, they never are), it would seem to be better policy to place the library as close as possible to Aerophysics, even if it meant doubling its distance from AMPD. Placement of new employees is another area in which consideration of the different divisional climates should be an important factor.

Concluding Remarks

The present study has provided numerical ratings of the relative importance of several of the important areas of management concern. The importance of the lower supervisors in what

may well be the most important single function in a research laboratory, the choice and definition of the problems on which it will work, suggests that one of management's top concerns should be the choice and training of people for these positions. The importance of items like knowledge of more than one field and work on a development project points out the closely allied problem of providing the best possible work mix for the individual researchers if they are going to develop their maximum potential. And, finally, the importance of the literature in both the choice of problems and in their solution provides management reason to give top priority to the task of making the library facilities better and better.

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